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FLAME SPEED DATA REDUCTION
AND CORRELATION USING A DIGITAL COMPUTER

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by Monsanto Research Corporation, Dayton,
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FOREWORD

This report describes work performed under Contracts AF 33(616)-7757 and AF 33(657)-7617, "A Research Program for Understanding the Mechanisms of Flame Inhibition," and AF 33(616)-7458, "Fire-Resistant High Temperature Hydraulic Fluids." The former contract was initiated under Project No. 6075, "Flight Vehicle Hazard Protection," Task No. 607505, "A Research Program for Understanding the Mechanisms of Flame Inhibition." The latter was initiated under Project No. 7340, "Non-Metallic and Composite Materials," Task No. 734008, "Power Transmission, Heat Transfer Fluids, and Other Forms of Energy Transfer Fluids."

The contracts were performed at the Dayton Laboratory of Monsanto Research Corporation. The first two contracts were sponsored by the Flight Accessories Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio with Mr. Benito P. Botteri serving as project engineer. The third contract was sponsored by the Directorate of Materials Processes, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio with Mr. Harold Adams as project engineer.

For Monsanto, the computer program was written by Dr. G. H. Ringrose of Monsanto Research Corporation and Dr. D. R. Miller and Dr. A. C. Pauls of Monsanto Chemical Company. Dr. G. B. Skinner served as project leader.

The authors are indebted to Dr. W. C. Hammann of Monsanto Chemical Company for the hand calculations that led to the adoption of the general mathematical approach. This contribution and the many helpful suggestions made by numerous people are acknowledged with gratitude. Particular assistance was given by Mr. D. J. Kaufman, also of Monsanto Chemical Company, who was instrumental in trouble shooting and expediting the machine solutions.

The routines were originally programmed and run on the IBM 704 computer in the Research and Engineering Division of Monsanto Chemical Company, St. Louis. Later the programs were adapted for solution by an IBM 7090, at the Aeronautical Systems Division, Wright-Patterson AFB, Ohio.

ABSTRACT

Two digital computer routines were developed to process flame speed data resulting from the burning of compounds in air and oxygen, and to correlate particular structural configuration with flame speed.

In both routines a high degree of flexibility has been incorporated to assure efficient utilization under several forseeable circumstances.

The first routine, FSC, processes the raw experimental data to obtain flame speeds, equivalence ratios, and the equivalence ratio at the maximum flame speed. This information is stored on a master magnetic tape for subsequent calculations.

The second routine, FSR, permits selection of specific data groups from the master tape for analysis. A linear model was chosen for the correlation.

This technical documentary report has been reviewed and is approved.

William C. Savage

WILLIAM C. SAVAGE
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FLAME SPEED DATA REDUCTION AND CORRELATION USING A DIGITAL COMPUTER

I. INTRODUCTION

Two Air Force-supported programs at this laboratory concern the relative rates of combustion of a number of chemical compounds. One program [AF 33(616)-7458] deals with the synthesis of potential high temperature hydraulic fluids and the other [AF 33(616)-7617] with increasing our understanding of the mechanisms of flame inhibition, the ultimate objective being the development of agents for extinguishing propellant fires.

Searches for effective fire-resistant fluids or propellant fire extinguishants would be systematized and expedited if a general method for characterizing, measuring, and predicting combustibility were at hand. Unfortunately, most flammability tests and specifications in use are so application-oriented or otherwise restricted as to be of only limited value for general use. A measure of the intrinsic ability of a material to support or inhibit combustion, as free as possible from influences peculiar to the testing procedure, is the first requisite. Given such a measure, there is then the possibility of relating combustibility to the molecular structures of materials tested and of predicting therefrom the combustibility of untested candidates.

This report describes computation routines designed to support the above approach. Flame speed - a state property of a combustible gas mixture - is the intrinsic measure of combustibility selected for use in characterization, correlation, and prediction. Earlier work, although limited to pure hydrocarbons burned in air, tends to confirm the approach adopted here.

The routines are programmed in the FORTRAN II language for IBM 7090 solution.

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II. THEORETICAL ASPECTS

Theoretical flame speed is commonly defined as the subsonic rate of perpendicular propagation of an infinite plane flame front through the quiescent combustible gas. External forces (for example, gravitational or magnetic fields) are presumed absent or insignificant, and the flame-induced flow is assumed to be laminar and one-dimensional.

When defined in this idealized manner, flame speed is a function only of the initial temperature, pressure, and composition of the combustible gas. It is thus an intensive state property of the gas, just as are density, enthalpy, viscosity, refractive index, and the like. Moreover, flame speed is a transport property dependent upon the rates of energy, momentum, mass, and chemical exchange accompanying combustion.

Prediction of flame speed from gas temperature, pressure, and composition is a long-standing goal of combustion research. A reasonably general and accurate method would be extremely useful in solving a range of practical and theoretical problems. Combustor and propulsion system design may be cited, in addition to the materials search problems underwriting the work of this report.

In principle, flame speeds can be predicted theoretically. Simultaneous solution of the differential equations of change is possible when all important physical-chemical properties (e.g., heats of reaction, reaction rate constants, density, diffusivities, emissivity, etc.) are known. Unfortunately, many of these properties are not yet known. Ccmbustion reaction mechanisms are normally quite complex and are consequently poorly understood. Much remains to be done, even in the identification of intermediate chemical species.

While theory is of little practical utility, empirical correlations offer considerable promise. Hibbard and Pinkel (Ref. 1) achieved a good correlation of maximum flame speed of 37 hydrocarbons (mixed with air) versus the concentrations of the various C-H bond types present. The relation used was of the form

$$u_{max} = \Sigma_j b_j (c_j)_{max} \tag{1}$$

The concentration $(c_j)_{max}$ of the j type bond is determined at the fuel-to-oxidizer ratio which yields the maximum flame velocity u_{max} and the corresponding influence coefficient for this bond is designated b_j. The average per cent deviation

between the measured and predicted maximum flame speeds was about 2% for the 37 hydrocarbons correlated.

The approach of Hibbard and Pinkel was extended by Hammann and Blake (Ref. 2) in calculation of flame speed coefficients of the various bond types in fuels containing oxygen, nitrogen, sulphur, boron, and silicon in addition to carbon and hydrogen. Their correlations were based upon data obtained experimentally by burning 142 model compounds and upon data reported by Gibbs and Calcote (Ref. 3). Several modifications of the correlation model, Equation 1, were tested and Equation 1A was found to provide the most acceptable correlation.

$$\frac{u_{max}}{(c_f)_{max}} = \sum_j b_j n_j \qquad (1A)$$

The number of j-type contributors occurring in each molecule of fuel is designated n_j.

While the agreement between the predicted and measured flame speeds was not as good as for hydrocarbons alone, the results convincingly supported the general utility of the linear correlation technique. The computer routines described in this report were used by Hammann and Blake.

DEFINITIONS

The following terms are used frequently throughout the report:

Contributor   A countable structural feature of a fuel molecule (e.g., each hydrogen bonded to a primary carbon in ethane, $\begin{array}{c}\text{H H}\\ \text{HC-CH}\\ \text{H H}\end{array}$, could be classed as a contributor).

Contributor number j An identifying code number which is assigned to each defined contributor (e.g., the primary-H contributor was assigned the code number 37).

Contributor count n_j (or n_{ij})   The number of j-type contributors contained in a molecule of fuel (or in a molecule of the ith fuel)(e.g., the contributor count of the contributor primary-H in the fuel ethane would be 6).

Fuel   A material that forms a combustible mixture when mixed with an oxidant. Included are impurities, additives, and all compounds not included in the gaseous oxidant. For totalling the contributor count for mixed or composite fuels,

it is assumed that the over-all fuel has additive properties of the compounds present. For example, if z_i is the mole fraction of compound i in the fuel, and n_{ij} is the count for contributor j, then

$$n_j = z_1 n_{1j} + z_2 n_{2j} + \ldots$$

Oxidant   The portion of the combustible mixture which includes the oxygen and inert gases but excludes the fuel.

Equivalence Ratio   The actual fuel-to-oxygen ratio divided by the fuel-to-oxygen ratio stoichiometrically required for complete combustion of the fuel oxidizer. This is a measure of the richness or leanness of the flame.

Standard Error   Synonymous with the statistical quantity "standard deviation."

Data Group   A unit of data pertaining to a single fuel-oxidant combination burned at various equivalence ratios but otherwise under identical conditions. The components of a data group in the order in which they are stored by the computer on master tape 6 are:

(a) Serial Number   Assigned sequentially by the computer in order of tape location.

(b) Fuel Name   Alphabetic and/or numeric representation of the fuel, e.g., (n-Pentene-2). A maximum of 12 characters (including blanks) is permitted.

(c) Fuel Numbers   Code numbers which are used to classify the types of fuel.

(1) Fuel Class Number   General fuel type (e.g., 01-organic aliphatic; 02-organic aromatic, 00-inorganic).

(2) Fuel Group Number   Denotes subclassification of fuel type (e.g., 06-saturated cyclic compound).

(3) Fuel Member Number   An arbitrary code number, used to indicate sequence of experimental analysis of a particular group.

Thus for the fuel cyclopropane the fuel number is 010601.

(d) Data Source Number   Designates the source of the data (e.g., 01-literature-, 02-experimental).

(e) Experimental Conditions Number   A code to distinguish data taken under different experimental conditions, such as temperature, pressure, per cent oxygen in oxidant, etc.

(f) Flame speed at unity equivalence ratio, u_{stoc} (cm/sec).

(g) Maximum flame speed, u_{max} (cm/sec).

(h) Fuel concentration at unity equivalence ratio, $(c_f)_{stoc}$ (molecules/cc).

(i) Fuel concentration at the conditions of maximum flame speed $(c_f)_{max}$ (molecules/cc).

(j) Equivalence ratio at the maximum flame speed, ϕ_{max}

(k) Number of different defined (i.e., coded) contributors in the fuel molecule.

(l) List of the contributor code numbers with their respective counts for the fuel considered.

III. DESCRIPTIVE OUTLINE OF THE CALCULATIONS

An analysis of the computations required to reduce the experimental data and perform the regression analyses led to the separation of the problem into two sections. The first section processes the raw experimental data and calculates the flame speeds, concentrations, and equivalence ratios. These quantities are then stored on a master reel of magnetic tape. The second section, namely, the flame speed regression section, uses this reel of magnetic tape as its input data. From these data, the regression coefficients of the flame speeds and other dependent variables are determined.

Corresponding to each of these sections is a Fortran routine that is described in detail in a later section. A general discussion of these routines follows.

DATA REDUCTION (Routine FSC)

The data reduction routine calculates the flame speed and related quantities from the raw data, tests these quantities for inconsistencies, and prepares or corrects the master reel of magnetic tape with acceptable data.

Flame Speed The calculations are based upon the conical (Bunsen) burner method for flame speed determination. Measured flows of the several components of the mixture are passed in laminar flow through a burner tube at a controlled temperature and pressure. A roughly conical flame front is stabilized at the mouth of the tube.

The large density gradient in the gas stream at the flame front permits the use of schlieren photographic techniques to record the flame profile. It is assumed that the flame is symmetrical about its vertical axis. Figure 1 is schlieren photograph of a typical flame cone.

The flame speed is determined by dividing the total volumetric gas flow rate by the area of the flame front. Since the flame cone photographed is seldom a "right circular cone," its surface area must be determined from measurements at several intermediate points. To do so, the diameter is measured at several heights of the cone as illustrated in Figure 2. The surface area between any two of these diameter measurements is assumed to be that of a frustrum of a right circular cone. The sum of the surface areas of these frustra gives a fairly accurate value of the true flame front area. Actually, the local flame speed is slightly above the average at the cone tip

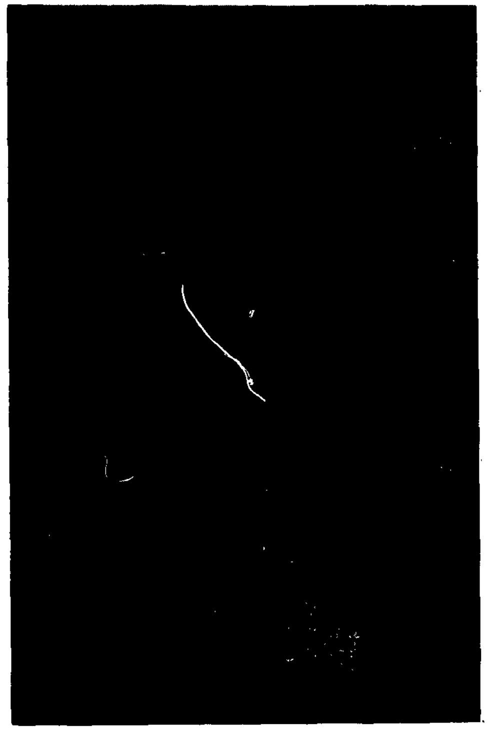

Fig. 1 Schlieren Photograph of a Flame Cone

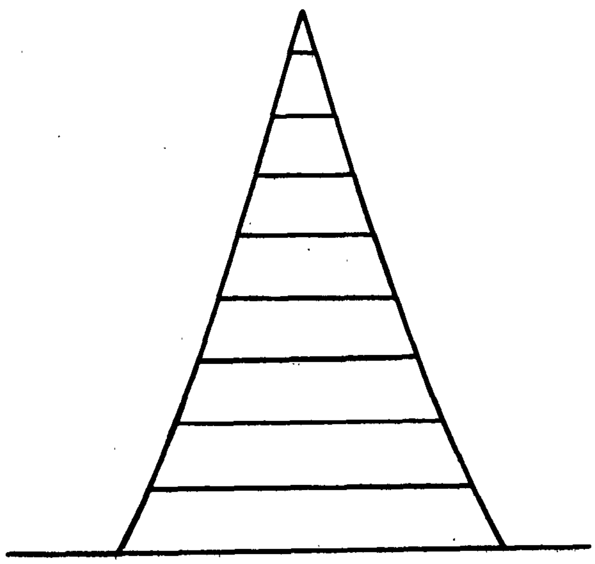

Fig. 2 Diagram of Flame Cone Profile

and slightly below the average at the base. Therefore, the calculated flame speed must be considered an average value only. Evidence has shown that there is a slight dependence of flame speed on the total volumetric flow rate of the gases, the burner part geometry, and the burner part temperature. Slight influences are also made by the method used to define the cone area (i.e., schlieren shadow, or radiant photography). However, by standardizing on one of the techniques, this variable can be eliminated.

Valid Data Tests Once a series of flame speeds has been obtained, it is necessary to determine the conditions for maximum flame speed (since the correlations proposed are based on conditions at the maximum flame speed). This is accomplished by fitting an empirical curve of flame speed vs. equivalence ratio (u vs. ϕ) to the data and solving the equation for the maximum. The flame speed at stoichiometric conditions ($\phi = 1$) is also determined.

If a maximum flame speed lies within tne data range the data are acceptable for further tests. If no maximum or a minimum is found within the data range, the data are not acceptable.

Storage on Magnetic Tape Data groups termed acceptable are stored on a master reel of magnetic tape for use by the regression routine.

Options The computational routine contains several options depending upon the form of the input data. These options permit sections of the computational procedure to be omitted. For example, a set of flame speed vs. equivalence ratio data available from previous calculations could be entered directly into the sequence, and the original raw data calculations would be by-passed. These options are detailed in Section VI.

FLAME SPEED REGRESSION (Routine FSC)

A multiple linear regression model similar to that used by Hibbard and Pinkel (Ref. 1)(but including a constant term) was selected:

$$y = b_o + \Sigma_j b_j n_j \tag{2}$$

Independent Variables In equation (2) the independent variables were chosen to be the contributor counts rather than the contributor concentration. This simplifies the prediction and data handling, and adds flexibility by making the "independent" variables more independent. This is true because the

contributor concentrations depend upon the mixture temperature, pressure, equivalence ratio, and oxidant composition, as well as upon fuel composition. A simple relation exists between the contributor counts and concentration, as shown in Equation 3:

$$c_j = n_j c_j \quad \text{molecules/cc} \qquad (3)$$

where c_f is the concentration of fuel in the combustible mixture. Multiplying Equation 2 by c_f gives the equivalent of the Hibbard-Pinkel model ($b_o = 0$).

<u>Dependent Variables</u> For the reasons mentioned above, the dependent variable y would be set equal to $u_{max}/(c_f)_{max}$ when the coefficients comparable to those published by Hibbard and Pinkel are wanted. However, this is not the only dependent variable of possible interest. In predictions of maximum flame speed, for example, it is necessary to predict fuel concentration (or fuel-oxidant ratio, or equivalence ratio) at maximum flame speed. This is most readily done by correlating fuel concentration (etc.) at maximum flame speed against contributor counts. Correlations at stoichiometric fuel-oxidant ratio may be equally interesting. To emphasize that such other dependent variables can be handled with equal facility, the indefinite dependent variable y is used.

<u>Coefficients</u> With the emphasis so far given to fuel composition, it is appropriate to recall that calculated b_j's are not constants. Values will depend on several or all of the following (depending on the definition of y):

1. initial mixture temperature
2. initial mixture pressure
3. some specification of fuel-oxidant ratio
4. oxidant composition
5. contributor definitions
6. dependent variable definition

The above list includes the primary state properties. Since experimental flame speeds (distinguished from theoretical flame speeds) are always obtained under conditions differing from the ideal, values of b_j will be related to:

7. experimental conditions (oxidant composition, temperature, pressure, etc.
8. source of data (laboratory, technique, journal reference, etc.

All listed factors should be considered when sets of coefficients are compared.

Block Regressions   Obtaining a full set of coefficients is basically a stepwise trial-and-error process. The trial-and-error enters in the definition of contributors (i.e., independent variables). Since it is not known at the outset which structural features will give the best correlations, it is necessary to accommodate definition of new contributors as the analysis progresses. In addition, it is desirable and most efficient to calculate certain coefficients using only a particular class of fuels. C-H bond coefficients, for example, are most readily and accurately determined from flame speed data on hydrocarbons. If accurately determined, a coefficient should be applicable unchanged in later regressions.

The above considerations indicated that a "block regression" procedure (certain coefficients held constant) would be most advantageous. This procedure may be expressed mathematically by Equation 4:

$$y - \Sigma_s b_s n_s = b_o + \Sigma_u b_u n_u \qquad (4)$$

The b_s coefficients represent those whose values are known, and are termed the "prespecified coefficients." The b_o and b_u coefficients are those to be determined by the regression analysis. The constant term b_o may be either calculated or prespecified as zero.

Block Selection Criteria   All of the data groups that are acceptable for regression analysis are stored on a single master reel of magnetic tape. Seven different accept-reject tests are available for selection of these data. The selecting criteria comprise (1) data group serial number, (2) fuel class number, (3) fuel class-group number, (4) fuel member number, (5) data source number, (6) experimental conditions number, and (7) fuel contributor content.

For flexibility, these tests may be ignored, or applied singly or in any combination. The tests are described in detail in the following section.

IV. MATHEMATICAL OUTLINE OF THE CALCULATIONS

FLAME SPEED DATA REDUCTION CALCULATIONS (Routine FSC)

Functions Performed   The functions performed by Routine FSC may be classed in five groupings. The portions of the computer program used in each function are enclosed in parentheses.

Function 1   (Subroutines EXPD 1 or EXPD 3)

Given:
(a) Combustion mixture, temperature and pressure
(b) Fuel stoichiometric oxygen demand
(c) Mole fraction of O_2 in oxidant
(d) Molar volume of fuel
(e) Volumetric flow rate of oxidant
(f) Flame envelope dimensions

Calculate:
(a) Volumetric flow rate of mixture
(b) Area of flame envelope
(c) Flame speed
(d) Equivalence ratio

(a) Volumetric flow rate of the mixture, q_m

$$w_x = q_x^*/22,414 \qquad \text{g-moles/sec} \qquad (5)$$

$$w_f = q_f/v_f \qquad \text{g-moles/sec} \qquad (6)$$

w_f and w_x are the molar flow rates of the fuel and oxidizer and q_f and q_x* are the volumetric flow rates in cc/sec (the latter at S.T.P.). v_f is the molar volume of the fuel and must be based on the same fuel density as q_f.

$$v_m = 62,366(t_m + 273.15)/P_m \qquad \text{cc/g-mole} \qquad (7)$$

where v_m is the molar volume of the mixture and t_m (°C) and P_{mv} (atm.) are the temperature and pressure of the mixture.

Therefore: $$q_m = (w_x + w_f)v_m \qquad \text{cc/sec} \qquad (8)$$

(b) Area of flame envelope, A

The increment of surface area ΔA_i between any two heights h_i and h_{i-1} is given by

$$\Delta A_i = \pi\left(\frac{D_{i-1} + D_i}{2}\right)\sqrt{(h_i - h_{i-1})^2 + \left(\frac{D_{i-1} - D_i}{2}\right)^2} \quad \text{cm}^2 \qquad (9)$$

where D_i is the measured diameter at the upper height and D_{i-1} is that at the lower height. The total surface area of the flame is calculated by summing these increments over the whole height

$$A = \sum_{i=1}^{n} \Delta A_i \qquad \text{cm}^2 \qquad (10)$$

(c) Flame speed, u

Once the total flame area has been determined, flame speed can be easily calculated:

$$u = q_m/A \qquad (11)$$

(d) Equivalence ratio, Ø

From its definition as the actual fuel-to-oxygen ratio divided by the stoichiometric fuel-to-oxygen ratio, the equivalence ratio is calculated:

$$\emptyset = (w_f/w_o)/(w_f/w_{ost}) \qquad (12)$$

where w_o is the molar flow rate of oxygen used in the experiment and w_{ost} is that rate required for complete reaction.

$$\text{But } w_o = w_x z_{ox} \qquad \text{g-moles/sec} \qquad (13)$$

$$\text{and } w_{ost} = w_f r_{st}/2 \qquad \text{g-moles/sec} \qquad (14)$$

where z_{ox} is the mole fraction of oxygen in the oxidant and where r_{st} is the number of atoms of oxygen required to completely oxidize one molecule of fuel.

$$\text{Therefore } \emptyset = w_f r_{st}/2 w_x z_{ox} \qquad (15)$$

Function 2 (Subroutine MAXM)

Given: A series of experimental values of flame speed vs. equivalence ratio. (The flow rates are the only controllable variables.)

Calculate: (a) Maximum flame speed
(b) Flame speed at stoichiometric conditions
(c) Equivalence ratio at maximum flame speed

(a) Maximum flame speed, u_{max}

Past work has shown that curves of u vs. ϕ generally are concave from below with a maximum in the vicinity of ϕ=1. Figure 3 is an example of such a curve.

Many of the curves are fairly symmetrical in the vicinity of the peak and are nearly parabolic in shape. Others are fairly asymmetrical and are better approximated by a higher order power series. To find the peak of a given series of measured values of u vs. ϕ, the data are fitted with an equation of the form

$$u = \sum_{r=1}^{R} a_r \phi^{r-1} \quad \text{cm/sec} \tag{16}$$

The method of calculating the "a" coefficients depends upon the number of points available, N. If N = 4, a perfect cubic fit (R = 4) is obtained by solution of the simultaneous equations

$$u_n = \sum_{r=1}^{R} a_r \phi_n^{r-1} \quad n = 1, \ldots R \tag{17}$$

If N >4, a least square cubic fit (R = 4) is obtained by the solution of the "normal regression equations."

$$\sum_{n=1}^{N} u_n \phi_n^{r-1} = \sum_{q=1}^{R} \left(a_q \sum_{n=1}^{N} \phi_n^{r+q-2}\right) \quad r = 1 \ldots R \tag{18}$$

The normal regression equations are the result of a mathematical treatment on the original polynomial, Equation 17. An explanation of the analysis may be found in statistics texts such as Hoel (Ref. 6).

Solution of these equations gives the set of "a" coefficients which minimize the residual sum of the squares:

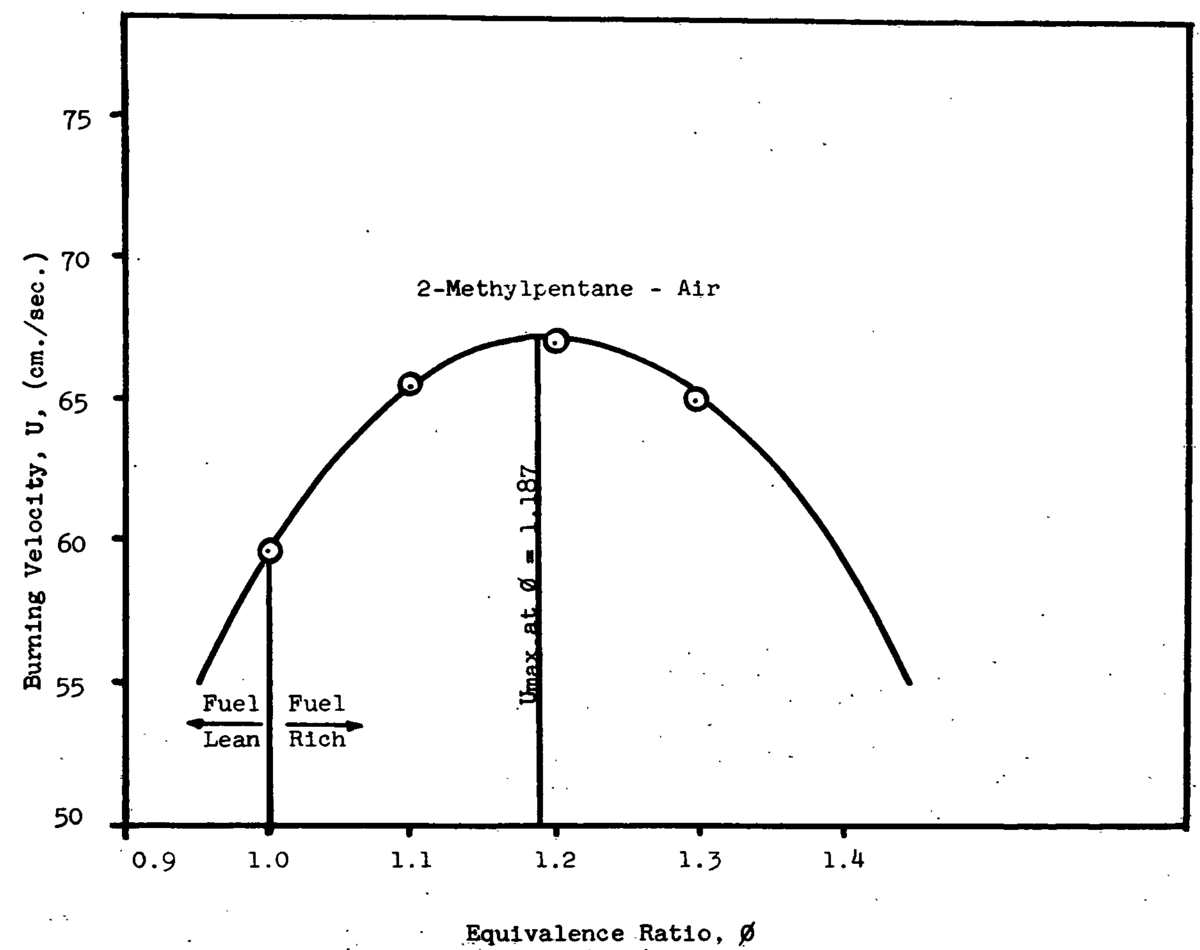

Fig. 3 Typical Curve Showing Burning Velocity, U, vs. Equivalence Ratio, Ø

$$Q = \sum_{n=1}^{N} (u_n - \hat{u}_n)^2 \tag{19}$$

where $\hat{u}_n$ represents a predicted value.

The standard deviation of u about $\hat{u}$ is

$$S = \pm\sqrt{Q/(N-R)} \quad \text{cm/sec} \tag{20}$$

If the calculated standard deviation is greater than the one specified, the cubic fit is declared unsatisfactory and a parabolic fit using Equation 18 with r=3 is tried. If the standard deviation is still too high, the data set is ignored.

If only three points are available, a perfect parabolic fit, r=3, is obtained in the manner of Equation 17. Less than three points are not considered since they cannot define a curve with a maximum.

(b) Equivalence ratios

(i) Cubic maximum Once the cubic fitting procedure has been satisfactorily completed, it is necessary to determine the maximum point (u_{max}, ϕ_{max}) of the curve. Two additional factors must be considered. The maximum velocity must occur within the data range considered, and a minimum velocity must not occur within the data range. If either of these conditions is violated, a parabolic fit is attempted.

Double differentiation of Equation 17 with r=4 gives

$$\dot{\hat{u}} = a_z + 2a_3\phi + 3a_4\phi^2 \tag{21}$$

$$\text{and} \quad \ddot{\hat{u}} = 2a_3 + 6a_4\phi \tag{22}$$

At the maximum

$$\dot{\hat{u}}_{max} = 0 \tag{23}$$

$$\text{and} \quad \ddot{\hat{u}}_{max} < 0 \tag{24}$$

Solving Equations 21 - 24 yields

$$\phi_{max} = (a_3/3a_4)(1 \pm \sqrt{1-3a_2a_4/a_3^2}\,) \tag{25}$$

$$\text{and} \quad 0 > \mp 2a_3 \; 1-3a_2a_4/a_3^2 \tag{26}$$

The inequality shows that the upper sign is to be used in Equation 26 when a_3 is positive, and vice versa.

For a real maximum to exist, three conditions must be fulfilled:

$$a_4 \neq 0 \tag{27}$$

$$a_3 \neq 0 \tag{28}$$

$$1-3a_2a_4/a_3^2 > 0 \quad \text{(real roots)} \tag{29}$$

(ii) Cubic minimum The equivalence ratio at the minimum point (u_{min}, ϕ_{min}) of the cubic equation must also be determined:

$$\phi_{min} = -(a_3/3a_4)(1 \mp \sqrt{1-3a_2a_4/a_3^2}) \tag{30}$$

The upper sign is understood to hold when a_3 is positive, and vice versa. This equivalence ratio must not lie within the data range.

(iii) Parabolic maximum When a satisfactory parabolic fit is obtained, ϕ_{max} is given by

$$\phi_{max} = -a_2/2a_3 \tag{31}$$

in which a_3 must be negative.

Function 3 (Executive routine)

Given:
(a) Combustion mixture temperature and pressure
(b) Fuel stoichiometric oxygen demand
(c) Mole fraction of O_2 in oxidant
(d) Equivalence ratio at maximum flame speed

Calculate:
(a) Fuel concentration at maximum flame speed
(b) Fuel concentration at stoichiometric conditions

(a) Fuel concentration at u_{max}, $(c_f)_{max}$ For any value of the equivalence ratio ϕ, the fuel concentration is given by

$$c_f = \frac{(6.0238 \times 10^{23})pm}{62,366(t_m + 273.15)(1 + r_{st}/2\phi z_{ox})} \tag{32}$$

molecules cc

Therefore $(c_f)_{max} = c_f$ evaluated at $\phi = \phi_{max}$ (33)

(b) Fuel concentration at $\phi = 1$, $(c_f)_{stoc}$

Similarly,

$$(c_f)_{stoc} = c_f \text{ evaluated at } \phi = 1 \quad (34)$$

Function 4 (Executive Routine)

Given: (a) Results listed above
(b) Composition, source, conditions and related input information

Action: Stores in memory only acceptable data groups

Function 5 (Subroutine Tape)

Given: (a) Acceptable groups stored in memory and on master tape 6
(b) Changes to be made in the data already on the master tape

Action: (a) Edit the existing master tape data
(b) Add new data groups to the master tape

In all cases, the input data, intermediate values, and output values are printed out at each step.

Function Options Four options are provided to permit portions of the program to be by-passed. The options would be exercised if portions of the experimental data had been processed previously or if outside data were to be used.

1. Complete calculation (Functions 1 through 4)
2. Partial calculation (Functions 2 through 4)
3. No calculation (Function 4)
4. Tape writing (Function 5 - follows successful execution of the other options)

FLAME SPEED REGRESSION CALCULATIONS (Routine FSR)

Functions Performed Routine FSR prepares the input data tape for the Esso Regression Analysis subroutine. Its operation may be considered in three stages:

Function 1

Given: (a) All data groups currently stored on master tape 6.
(b) A list of data group accept/reject tests

Action: Selects and stores up to 300 data groups passing the accept/reject tests

Seven different tests are available for accepting or rejecting data groups now recorded on the master tape for the regression analysis. These tests may be employed in any combination desired, including omission of any or all. A limit of 300 acceptable data groups has been imposed for each regression run. If more than 300 could pass the tests, only the first 300 doing so are accepted for regression.

(a) Data group serial number test   Those data groups whose serial numbers (machine assigned in order of tape position) are given in an input specification list are unacceptable.

(b) Fuel class test   Only those data groups whose fuel class numbers are specified in an input list are acceptable.

(c) Fuel group test   Only those data groups whose fuel class-group numbers are specified in an input list are acceptable.

(d) Fuel member test   Only those data groups whose fuel class-group-member numbers are not specified in an input list are acceptable.

(e) Data source test   Only those data groups whose source number corresponds to an input source number are acceptable.

(f) Experimental conditions test   Only those data groups whose experimental conditions number corresponds to an input conditions number are acceptable.

(g) Contributor count tests   Data groups may be acceptable or unacceptable depending on the presence or absence of given contributors in the fuel molecule. In addition, the counts of any specified contributors may be assumed zero whether they are zero or not on the master tape.

Function 2

Given: (a) All data groups selected as above
(b) Dependent variable numerator and denominator code numbers
(c) A list of prespecified coefficients with their corresponding contributor numbers

Calculate: Adjusted and scaled dependent variables for regression

(a) Dependent variable calculation The basic regression problem is to determine the b_u and b_o coefficients in the equation

$$y = b_o + \sum_u b_u n_u \tag{35}$$

such that the sum of the squares of the difference between the actual and predicted values is minimized. Routine FSR provides the option to define the dependent variable y provided the independent variables are still contributor counts. Thus, if regression of the maximum flame speed on contributor concentrations at maximum flame speed is desired, y would be defined

$$y = u_{max}/(c_f)_{max} \tag{36}$$

The dependent variable y may be any quantity expressible as a simple ratio of any two of the following quantities:

Quantity	Identification Number
1.0	1
u_{stoc}	2
u_{max}	3
$(c_f)_{stoc}$	4
$(c_f)_{max}$	5
ϕ_{max}	6

(b) Dependent variable adjustment If it is desired to prespecify (and therefore not calculate) some of the b coefficients in a given problem, it is necessary to adjust

the dependent variable by subtracting the contributions associated with the prespecified coefficients. Equation 37 indicates the procedure

$$y'_i = y_i - \sum_s b_s n_{is} \tag{37}$$

(c) Dependent variable scaling. To avoid exceeding the numerical limit of the computer (10^{38}) during the regression calculations, all of the final dependent variables are scaled (i.e., multiplied by a constant factor)

$$Y_i = y'_i \cdot 10^E \tag{38}$$

so that the largest Y_i in a given problem does not exceed 1000.

Function 3

Given: (a) All data obtained above
(b) Input lists of overriding regression control data (optional)

Action: For each valid regression problem store on tape 7:

(a) Output page heading
(b) Regression control data
(c) Independent variable values (contributor counts)
(d) Adjusted and scaled dependent variable values

The regression analysis routine, a modification of SHARE E-R-MPR2, requires input data for the control of calculation and printing. One of the functions of routine FSR is to supply the needed data in the proper form. Although this is done automatically using internally stored values, input control data may be given if it is desired to override any of these values.

In all cases the important input data and intermediate and output values are printed for each function listed above.

V. THE COMPUTER PROGRAM

FLAME SPEED DATA REDUCTION (Routine FSC)

Routine FSC consists of an executive, or master control program and the eight subroutines listed below.

1. EXPD1
2. EXPD3
3. MAXM
4. TAPE
5. CROUT
6. INPUT
7. VDECOM
8. DECDCP

Section IV contained a brief outline of the functions of the executive routine and the first four subroutines listed above. Here, these shall be discussed in more detail.

Executive Routine The executive routine controls the selection of five of the eight subroutines. The first data card in each group contains information regarding the option to be performed, the use of EXPD1 or EXPD3 and the use of MAXM. The executive routine reads this card and sequences the operations accordingly. Diagnostic code numbers are present in each of the subroutines and if any of these are exercised the executive routine will cause the printout of a diagnostic. If subroutine MAXM indicates that the data processed were satisfactory, the executive routine will store the pertinent values in memory prior to their addition to the master tape. Two small calculations, $(c_f)_{st}$ and $(c_f)_{max}$ are also made. It has been attempted to indicate each step in the actual program with "comment cards", and for convenience a nomenclature list precedes each routine. These can be found in Appendix A.

Subroutines EXPD1 and EXPD3 Both subroutines perform the same basic calculation of total cone area, flame speed, and equivalence ratio. However, the respective data outputs differ slightly. It was considered less confusing if each alternative had its own subroutine. Which subroutine to use is determined mainly by the intended use of the data after processing.

If the data to be processed are to be considered for addition to the master tape, subroutine EXPD1 should be used. In this subroutine, one experimental run number pertains to the entire data group and the input and output are set up accordingly.

If a set of control data are run sequentially, subroutine EXPD3 should be used. Each calculation is listed sequentially in the output to avoid confusion of the output with that from EXPD1. Sample printouts from both subroutines may be found in Appendix A.

<u>Subroutines MAXM and CROUT</u> Subroutine MAXM analyzes the data to see if either a valid cubic maximum or a parabolic maximum occurs within the data range. Subroutine CROUT solves the equations generated for the regression coefficients. As the logic used in subroutine MAXM is more involved than in the others, a brief stepwise description is presented.

1. If the number of experiments (or points) per data group is 1 or 2, signal that the data are "bad" and return to the executive routine. If there are 3 points, go to step 6; otherwise go to step 2.

2. Calculate the cubic coefficients either from the cubic polynomial (4 points) or from the "normal regression equations" (more than 4 points), as indicated in Section IV. If the calculation is successful, go to step 3; if not, to step 6.

3. Check cubic maxima criteria (coefficients zero or imaginary square root). If all are satisfied go to step 4; if not, to step 6.

4. Calculate ϕ_{max} and ϕ_{min}. Check for ϕ_{max} inside data range and ϕ_{min} outside data range of ϕ. If so, go to step 5; if not, to step 6.

5. Calculate u_{stoc}, u_{max}, $\hat{u}_n$, absolute and per cent differences between u_n and $\hat{u}_n$, and standard deviation S. If S is less than or equal to a specified value, signal the data "good" and return to the executive routine; if greater, signal the data "bad" and return to the executive routine.

6. Calculate the parabolic coefficients from the quadratic polynomial (3 point) or from the "normal regression equations" (more than 3 points). If the calculation succeeds, go to step 7; if not, to step 9.

7. Check for negative coefficient a_3 (curve concave downwards). If so, calculate ϕ_{max} and go to step 8; if not, to step 9.

8. Check for ϕ_{max} inside ϕ data range. If so, go to step 5; if not, to step 9.

9. Signal the data "bad" and return to the executive routine.

Subroutine TAPE This subroutine controls all operations that change the contents of the master tape. The first portion of the routine scans the tape and makes the alterations to the data groups that were specified on an input data card. The second section permits the alteration or addition of contributor code numbers and names. The third section adds to the master tape the new data groups that were either approved by MAXM or entered via option 3. The final section is used only for the initial makeup of the master tape. Once the tape contains some data the other portions of the program may be used without a sequencing diagnostic.

Subroutines INPUT, VDECOM, and DECDCP These subroutines facilitate preparation of the input data cards by permitting a variable width format. The complete card format is described in Section VI.

FLAME SPEED REGRESSION (Routine FSR)

Routine FSR prepares the input data for the E-R-MPR2 Esso Multiple Regression subroutine. It does not alter the input data (with the exception of scaling the dependent variable), but serves only for selecting the appropriate data for the regression analysis. In addition, control data are supplied for the Esso program.

Accept/Reject Tests Seven tests are provided for accepting or rejecting data groups. The first six tests are simple yes/no choices and were explained in Section IV. These tests are listed below.

1. Data group serial number test
2. Fuel class test
3. Fuel group test
4. Fuel member test
5. Data source test
6. Experimental conditions test

Test 7, the contributor count test, is more complicated and will be explained here in detail.

Data groups will be found acceptable or unacceptable depending upon the presence or absence of particular contributors in the fuel molecule. In addition, the counts of any contributor may be set equal to zero. The code numbers and test operation are listed below.

zero test - The count of the specified contributor(s) is set to zero

one test - The count of this contributor may be either zero or positive.

two test - The count of this contributor must be zero or the group will be rejected.

three test- The count of this contributor must be positive or the group will be rejected.

four to nine tests - Six tests are available to select data groups on the basis of a particular contributor content. The acceptance of a data group may be <u>conditional</u> upon it containing (+) and/or <u>excluding</u> (-) a certain number of a list of contributors. An example should clarify this.

<u>Example</u>

The data card types are given an alphabetic identification. The contributor count tests are specified on a "P" type card and the conditional tests on a "Q" type card.

<u>(a) Sample P-type Card</u> 1, 0, 15, 1, 16, 0, 27, 4, 29, 5, 32, 3, 33, 5, 34, 4, 37, 2, 40, 6, 61, 0.

<u>Interpretation</u>

Apply zero test (0) to contributors number 1-14, 16-26, 61 and up
Apply one test (1) to contributor number 15
Apply two test (2) to contributors number 37-39
Apply three test (3) to contributor number 32

The above tests are specific; the following are conditional:

Apply four test (4) to contributors
number 27, 28, 34-36
Apply five test (5) to contributors
number 29-31, 33
Apply six test (6) to contributors
number 40, 41

(b) Corresponding Q-type Card

+3, -2, +1

Interpretation

Four test; the data group must contain (+) at least 3 contributors from the list 27, 28, 34-36.

Five test; the data group must not contain (-) at least 2 contributors from the list 29-31, 33.

Six test; the data group must contain either contributor 40 or 41.

NOTE: Conditional tests 7 to 9 were not used in the example.

Dependent Variable Limitations   Up to 10 different dependent variables may be regressed in a single computer run (problem numbers 1 to 10). All problems in the same run share a common list of regression control data and operate on the same set of selected data groups.

Regression Control Data   The regression analysis subroutine, a modification of SHARE E-R-MPR2, requires several pieces of information for the control of calculation and printing. One function of routine FSR is to supply the needed data in the proper form. This is done automatically using internally stored values. Only when it is desired to override one or more of the internal values is it necessary to supply input control data. Internally stored values are given in the following list.

Item	Description	Built-in Value
Dec. 1	Tolerance	0.001*
2	F value for entering variable	0.00002*
3	F value for removing variable	0.00001*
Int. 1	Problem number	calculated
2	Number of variables	calculated
3	Number of points (data groups)	calculated
4	Weighting factors given	1 (no)
5	Intermediate steps printed	0 (yes)*
6	Raw sums of squares and cross products printed	1 (no)*
7	Averages to be printed	1 (no)*
8	Residual sums of products to be printed	1 (no)*
9	Partial correlation coefficients to be printed	1 (no)*
10	Predicted values (Y_i's) to be printed	0 (yes)*
11	Constant term (b_o) to be assumed non-zero	1 (no)*

Values marked with an asterisk may be overridden by input values.

VI. USE OF THE COMPUTER PROGRAMS

Both routines have been written in the standard FORTRAN II language compatible with most large-scale computing equipment. A maximum of four magnetic tape units are required in addition to any tape units used for input-output operations. The routines, as presented in Appendices A and B, are programmed to be compatible with the IBM 7090 Monitor system, with Tape 2 designated as the input and Tape 3 as the output.

Two additional routines have been included to avoid the storage of the master data tape over a period of time. Routine FSRDM will prepare a master data deck, or modify an existing data deck from information contained on the master data tape. Routine FSRTL will prepare a tape from the master data deck. These routines are presented in Appendix C.

INPUT DATA DECK PREPARATION

The programs accept the standard IBM type, 80-column punched cards. However, only columns 1 to 72 may contain information to be processed by the computer. It is recommended that columns 73-80 be used for some type of identification both for the users standpoint as well as for the computing center.

All decimal input data and most integer input data are processed via subroutines VDECOM and DECDCP before being used in the computation portion of the main routine. The use of these subroutines simplifies data card preparation to the extent that field widths may be neglected. It is only necessary to provide a blank space or a comma between entries on the data cards. One restriction is imposed though. No entry may end in column 72 on the data card.

FLAME SPEED DATA REDUCTION

The input data deck may consist of several sets of cards depending on the nature of the data and the option applicable. If only the calculated flame speed is of interest, an unlimited number of data sets may be entered. If, however, options 1, 2, or 3 are used for the purpose of adding data groups to the master tape, an option 4 must follow every 20 sets or less. This limitation is imposed because of the internal storage requirements of the program. Options 1, 2, or 3 may be run in any order.

To simplify the makeup of the data decks, each card fulfilling a specific purpose has been assigned an alphabetic code letter. Below are listed the data deck requirements for each of the options available. The actual makeup of the cards follows.

Option 1 Calculation of Flame Speeds from Raw Data

The first four card types set up the calculation sequence and define certain general conditions. The remaining cards contain the experimental measurements for each flame photograph. Thus, for a total of N_2 photographs, the card order would be:

Card Order	Card Type
1	A
2	X
3	B
4	C
5 to $N_2 + 4$	D

Certain entries on the A card determine whether or not a full calculation or just the flame speeds are required. If the latter is the case, any number of these sets may be submitted, otherwise the maximum number before a tape writing sequence is 20. N_2 is limited to 10.

Option 2 Calculations for Given Equivalence Ratios and Flame Speeds

The first four card types are similar to those mentioned above. The last card contains the predetermined flame speeds and equivalence ratios.

Card Order	Card Type
1	A
2	X
3	B
4	C
5	E

Option 3 All Final Values Given

Only the information on the first three card types is required.

Card Order	Card Type
1	A
2	X
3	B

Option 4 Tape Writing and Editing

The first card type remains the same. The second card type contains information about the remaining two card types.

Card Order	Card Type
1	A
2	F
3	G
4	H

Card Content by Card Type All numerical input data for routine FSC are processed by subroutines VDECOM and DECDCP. In the listings below, all integer quantities are designated Int. and all floating point quantities (e.g. .002 or 2.E-3 or 2.-3) are designated Dec. The only restrictions on preparation of these cards are that column 72 must be blank and each entry must be separated by at least one blank or comma. Readin of alphanumeric input is accomplished with an "A" format and the card column designations below must be maintained.

A Card

Entry 1		Int.	1000, card identification
2		Int.	Run number (1 to 9999)
3		Int.	4, number of integer entries following
4		Int.	Option number (1 to 4)
5		Int.	EXPD, subroutine number (1 or 3)
6		Int.	N_o, number of inhibitors present
7		Int.	MAXM, subroutine switch (0-use, 1-bypass)
8		Int.	1, number of decimal entries following
9		Dec.	0., dummy entry

X Card

	Columns		
Entry 1		Int.	0000, card identification
2		Int.	0, dummy entry
3		Int.	0, dummy entry
4	13-24	Alphabetic, fuel name	
5	25-36	Alphabetic, date	
6	37-48	Alphabetic, inhibitor name	
7	49-60	Alphabetic, inhibitor name	

A maximum of ten inhibitor names may be entered. These names must follow sequentially on the data cards and must occupy twelve columns per name. Columns 1 to 12 on each card, however, must contain the three integer entries listed above. Thus, if N_0 were 4, the fuel name, data and three inhibitor names would go on the first X card while the fourth name would appear in Columns 13 to 25 of the second X card.

B Card

Entry 1	Int.	2000, card identification
2	Int.	Run number
3	Int.	7, number of integer entries following
4	Int.	Option number (1 to 3)
5	Int.	Fuel class number (0 to 99)
6	Int.	Fuel group number (0 to 99)
7	Int.	Fuel member number (0 to 99)
8	Int.	Data source number (1 to 9999)
9	Int.	Experimental condition number (1 to 9999)
10	Int.	N_1, number of contributors listed on following B cards (1 to 100)
11	Int.	5, number of decimal entries following
12	Dec.	Flame speed at stoichiometric conditions (cm/sec)*
13	Dec.	Maximum flame speed (cm/sec)*
14	Dec.	Fuel concentration at stoichiometric conditions (molecules/cc)*
15	Dec.	Fuel concentration at maximum flame speed (molecules/cc)*
16	Dec.	Equivalence ratio at maximum flame speed*

*Enter 0.0 when these values are not known (i.e., for options 1 and 2)

B Card Continuation

Entry 1	Int.	2001, card identification
2	Int.	Run number
3	Int.	N_2, number of integer entries following ($N_2 \leq 10$)
4 to N_2+3	Int.	Contributor code numbers
N_2+4	Int.	N_2, number of decimal entries following
N_2+5 to $2N_2$+5	Dec.	Contributor count

If more than ten contributors are present, additional continuation cards may be used. For each subsequent continuation card increase the card identification number by one (1).

C Card

Entry	1	Int.	3000, card identification
	2	Int.	Run number
	3	Int.	2, number of integer entries following
	4	Int.	Option number (1 or 2)
	5	Int.	N_3, number of experiments in data group (EXPD1) or number of experimental runs(EXPD3)(i.e., number of D cards)
	6	Int.	7, number of decimal entries following
	7	Dec.	Mixture temperature (^{o}C)
	8	Dec.	Mixture absolute pressure (mm Hg)
	9	Dec.	Stoichiometric oxygen ratio (atoms oxygen/molecule fuel)
	10	Dec.	Mole fraction O_2 in oxidant
	11	Dec.	Volume per mole of fuel at given fuel flow rates (cc/gram-mole)
	12	Dec.	Maximum allowable standard deviation in u vs. Ø curve for addition to tape (assumed 1.0 cm/sec if 0.0 entered)
	13	Dec.	Actual distance between teeth tips seen on schlieren photograph (cm) (assumed to be 0.2 cm if 0.0 entered)

D Card

Entry	1	Int.	4000, card identification
	2	Int.	Run number
	3	Int.	2, number of integer entries following
	4	Int.	1, option number
	5	Int.	N_4, number of diameter measurements listed on continuation card (1 to 100)
	6	Int.	6, number of decimal entries following
	7	Dec.	Fuel flow at mole volume of entry 11 on C card
	8	Dec.	Oxidant flow at STP (cc/sec)
	9	Dec.	Mole fraction of inhibitor in final mixture
	10	Dec.	Measured peak height (arbitrary units)
	11	Dec.	Reference length (cm)
	12	Dec.	Reference length (arbitrary units)

D Card Continuation

Entry	1	Int.	4001, card identification
	2	Int.*	Run number
	3	Int.	N_5, number of integer entries following
	4 to N_5 + 3	Int.**	Station height of diameter measurement (1 = cone base)
	N_5 + 5 to $2N_5$ + 5		Cone diameter (arbitrary units)

*For data processing by subroutine EXPD1, the run number on each D card must be the same as that on the A, B and C cards. For processing by routine EXPD3, the run number is to be incremented by one for each subsequent D card.

**The station heights correspond to the "teeth locations referred to in the C card description. The distance between twenty reference teeth was accurately known. As all flame speed measurements were made on a microfilm reader, it was found to be more accurate and more convenient to measure the flame diameters and teeth spacing in any suitable units (say mm) and have the computer rescale the measurements to the desired units.

E Card

Entry	1	Int.	5000, card identification
	2	Int.	Run number
	3	Int.	1, number of integer entries following
	4	Int.	2, option number
	5	Int.	N_3, number of flame speed - equivalence ratio entries (1 - 10)

E Card Continuation

Entry	1	Int.	5001, card identification
	2	Int.	Run number
	3	Int.	1, number of integer entries following
	4	Int.	0, dummy entry
	5	Int.*	N_3, number of flame speed equivalence ratio entries
	6 to 6 + N_3	Dec.	

*N_3 is entry 5 on the C card and must not have a value exceeding 10.

F Card

Entry	1	Int.	6000, card identification
	2	Int.	Run number
	3	Int.	5, number of integer entries following
	4	Int.	4, option number
	5	Int.	N_6, number of G-card groupings to follow (0 to 20)(contributor count changes)
	6	Int.	N_7, number of entry pairs on H-card (0 to 50)(contributor name changes)
	7	Int.	7, for initial tape makeup, otherwise zero
	8	Int.	0, for other than last data card set; 1, for last set
	9	Int.	1, number of decimal entries to follow
	10	Dec.	0., dummy entry

G Card

Entry	1	Int.	7000, card identification
	2	Int.	Run number
	3	Int.	2, number of integer entries following
	4	Int.	Data group serial number
	5	Int.	N_8, number of entry pairs in contributor count change list (0 to 90)
	6	Int.	1, number of decimal entries following
	7	Dec.	0.,dummy entry

G Card Continuation

Entry	1	Int.	7001, card identification
	2	Int.	Run number
	3	Int.*	N_9, number of integer entries following (0 to 10)
	4 to N_9+3	Int.	Contributor number
	N_9 +4	Int.	N_9, number of decimal entries following
	N_9+5 to 4+2N_9	Dec.	Contributor count

*If N_8>10 additional continuation cards will be required. The card identification number must be incremented by one on each continuation card.

H Card

Columns 1 to 4	0000
6	0
8	0
13 - 16	contributor number
25 - 28	contributor number
⋮	
61 - 64	contributor number
* 19 - 24	alphabetic contributor name
31 - 36	alphabetic contributor name
⋮	
67 - 72	alphabetic contributor name

*There are to be five entry pairs per H card. If N_7 from the F card is greater than 5, continue the listing on additional cards at five pairs per card.

Fortran Routine The Fortran II program is listed in Appendix A with sample printouts. Duplicate decks of this program are available.

FLAME SPEED REGRESSION

The number and type of cards comprising the data deck will depend upon the number of tests and changes wanted. To facilitate the deck makeup, each specific data card has been given an alphabetic code letter from I through U. Card types I, J, K, and T in the deck are mandatory with the K-type card containing control integers governing the number and type of all but one of the remaining cards.

Card Order	Card Type
1	I
2	J
3	K
Next, unless $N_2 = 0$	L
Next, unless $N_3 = 0$	M
Next, unless $N_4 = 0$	N
Next, unless $N_5 = 0$	O
Next, unless $N_6 = 0$	P

Card Order	Card Type
Next, unless $N_7 = 0$	Q
Next, unless $N_8 = 0$	R
Next, unless $N_9 = 0$	S
Next	T } *
Next, unless $N_{10} = 0$	U } *

*N_1 pairs of these cards may be used ($N_1 \leq 10$). The T card contains N_{10} and hence governs the use of the U type card.

Card Content by Card Type With exception of the I, J, R and U type cards, all input data to routine FSR are integers. A fixed format is used to accomplish this with four spaces allotted to each entry (18I4). The type U cards are decomposed in subroutines VDECOM and DECDCP with the same limitations as described for routine FSC. When card column designations are given, they must be adhered to.

I Card - Subtitle Information for Routine FSR Printout

Column	1	Alpha	Blank
	2-72	Alpha	Subtitle

J Card - Title for Regression Program Printout

Column	1	Alpha	One (1)
Column	2-72	Alpha	Title

K Card - Routine FSR Control Card

Entry	1	Int.	Regression run number (1 to 9999)
	2	Int.	N_1, number of dependent variable choices in this run
	3	Int.	N_2, number of entries in input list (L card) of unacceptable data group serial numbers (0 to 300)
	4	Int.	N_3, number of entries in input list (M card) of acceptable fuel class numbers () to 13)
	5	Int.	N_4, number of entries in input list (N card) of acceptable fuel class group numbers (0 to 40)
	6	Int.	N_5, number of entries in input list (O card) of unacceptable fuel class-group-member numbers (0 to 80)
	7	Int.	Acceptable data source number (0 to 999, 0 means all sources acceptable).

Entry	8	Int.	Acceptable experimental conditions number (0 to 999, 0 means all conditions acceptable)
	9	Int.	N_6, number of entry pairs in input list (P card) of contributor count tests (0 to 200)
	10	Int.	N_7, number of entries in input list (Q card) of conditional count test criteria (0 to 6)
	11	Int.	N_8, one if overriding decimal regression control data (R card) to be read; otherwise zero
	12	Int.	N_9, number of entry pairs in input list (S card) of overriding integer regression control data (0 to 7)
	13	Int.	Highest contributor number in use (1 to 200, higher ones ignored)
	14	Int.	1, for the last run, otherwise zero

<u>L</u> Card

Entry 1 to N_2	Int.	Unacceptable data group serial numbers ($N_2 \leq 300$)

<u>M</u> Card

Entry 1 to N_3	Int.	Acceptable fuel class numbers ($N_3 \leq 20$)

<u>N</u> Card

Entry 1 to $2N_4$	Int.	Acceptable fuel class-group numbers ($N_4 \leq 40$) paired.

<u>O</u> Card

Entry 1 to $3N_5$	Int.	Unacceptable fuel class-group-members ($N_5 \leq 80$) in trios.

<u>P</u> Card (see "Contributor Count Tests")

Entry 1,3 $2N_6-1$	Int.	Contributor number	N_6 pairs
2,4 $2N_6$	Int.	Contributor count test	($N_6 \leq 200$)

<u>Q</u> Card

Entry 1 to N_7	Int.	Conditional count test criteria. First entry goes with test 4, second with 5, etc. ($N_7 \leq 6$)

R Card (see "Regression Control Data")

Columns 1 to 10	Dec.	Tolerance
11 to 20	Dec.	F value for entering variable
21 to 30	Dec.	F value for removing variable

S Card (see "Regression Control Data")

Entry 1,3	$2N_9-1$	Int.	Integer regression control item number
2,4	$2N_9$	Int.	Overriding integer regression control data

$N_9 \not\leq 7$

T Card

Entry 1	Int.	Dependent variable numerator identification number (1 to 6)
2	Int.	Dependent variable denominator identification number (1 to 6)
3	Int.	N_{10}, number of entry pairs in input list (U card) of prespecified regression coefficients for this problem (0 to 50)

U Card

Entry 1	Int.	1, card number
2	Int.	Run number
3	Int.*	N_{11}, number of integer and decimal pairs to follow
4 to $3+N_{11}$	Int.	Contributor number
$N_{11}+4$	Int.	N_{11}
$N_{11}+5$ to $4+2N_{11}$	Dec.	Prespecified coefficient

*If $N_{10} > 10$ additional U type cards will be required until all of the contributor numbers and coefficients are entered. The card number must be incremented by one for each additional card.

Fortran Routine The Fortran II program for routine FSR is listed in Appendix B. Duplicate decks of this program are available.

MASTER DATA DECK LOADING AND MODIFICATION

Routine FSRTL The only data cards required by the routine are those of the master data deck itself. The card image of this deck will be read onto logical tape 6 which will then be given an end of file and rewound.

Routine FSRDM   If it is desired to update the master data deck, routine FSRDM will cause any or all of the data groups on the master tape to be punched. The master tape must be logical tape 6. All control data for the routine are integers and a fixed format is used which provides a six-column field width (12I6).

First control card for Routine FSRDM

Entry	1	Int.	Number of data groups in the master data card deck
	2	Int.	N_1, number of data groups which have been altered since last deck makeup
	3	Int.	Punch contributor name list? (1-yes, 2-no)
	4	Int.	Punch dependent variable name list? (1-yes, 2-no)

If none of the data groups have been modified, $N_1 = 0$ and the routine will punch only those data groups added since the last makeup. If $N_1 \neq 0$ an additional control card is required.

Second control card for Routine FSRDM

Entry 1 to N_1	Int.	Serial number of data groups that have been modified since last deck makeup.

The Fortran II programs for routines FSRTL and FSRDM are listed in Appendix C. Duplicate decks of these programs are available.

VII. NOMENCLATURE

a	Power series fitted coefficient
A	Area of flame schlieren cone, cm^2
b	Regression coefficient
c	Number concentration, cm^{-3}
D	Diameter of flame schlieren cone, cm
E	Dependent variable scaling exponent
h	Height above burner port, cm
n	Contributor count, no./molecule
N	A number
p	Absolute pressure, mm Hg
q	Volumetric flow rate, cm^3/sec.
Q	Residual sum of squared differences
r	Atoms of oxygen per molecule of fuel
R	Maximum value of r subscript
S	Standard deviation
t	Temperature, ^{o}C
u	Flame speed, cm/sec.
v	Molar volume, cm^3/g-mole
w	Molar flow rate, g-moles/sec.
x	Independent variable
y	Dependent variable
Y	Adjusted and scaled dependent variable
z	Mole fraction
Δ	Increment prefix
π	3.14159 ···
Ø	Equivalence ratio

Subscripts

f	Of fuel
i	Data group index, block regression
j	Contributor index (or number)
m	Of combustible mixture
min	At minimum of cubic fitting equation
max	At maximum flame speed
n	Height index
o	Of oxygen, or zero index
p	At peak of flame cone
q	Dummy r index
r	Term index, u-Ø curve
s	Specified (or prespecified)
stoc	Stoichiometric
u	Unspecified (to be calculated by regression)
x	In oxidant

Superscripts

$\wedge$	Calculated from a fitted equation
*	At STP ($0^{o}C$, 760 mm Hg abs.)
'	Adjusted
$\cdot$	First derivative
$\cdot\cdot$	Second derivative

REFERENCES

1. Hibbard, R. R., and Pinkel, B., J., Am. Chem. Soc., 73, 1622 (1951).
2. Hammann, W. C. and Blake, E. S., et al, ASD-TDR-62-405, p. 39 ff.
3. Gibbs, G. J., and Calcote, H. I., J. Ind. Eng. Chem., 4, 226 (1959).
4. Miller, D. R., and Olt, R. G., Monsanto Chemical Company, RD-61-Fin. No. 1420 (1961).
5. Barnett, H. C., and Hibbard, R. R., editors, Report 1300, Nat. Adv. Comm. Aero., Washington, D. C. (1957).
6. Hoel, P. G., Introduction to Mathematical Statistics, John Wiley, New York, 1953, p. 90.

APPENDIX A

Fortran Program and Sample Printouts for Routine FSC

ROUTINE FSCX

FLAME SPEED CALCULATION EXECUTIVE PROGRAM

```
CFSCX  2018  FEB  20 ,1962   FLAME SPEED CALCULATIONS   MOD 2
C
C       EXECUTIVE ROUTINE FOR FLAME SPEED CALCULATIONS   MRC - DAYTON
C
C       NOMENCLATURE
C
C         A1(I) AND A2(I) - FUEL NAME
C         B1(K,I)         - NUMBER OF STRUCTURAL CONTRIBUTORS PER MOLECULE
C         CMX             - FUEL CONCENTRATION AT MAXIMUM FLAME VELOCITY
C                                (MOLECULES / CC )
C         CSTOC           - FUEL CONCENTRATION AT STOICHIOMETRIC
C                                CONDITIONS  (MOLECULES / CC.)
C         DU AND TE       - FIRST AND SECOND HALVES OF DATE
C         I, K, AND N     - COUNTING INTEGERS
C         I1A(I)          - FUEL CLASS  NUMBER
C         I1B(I)          - FUEL GROUP  NUMBER
C         I1C(I)          - FUEL MEMBER NUMBER
C         I2(I)           - DATA SOURCE NUMBER
C         I3(I)           - EXPERIMENTAL CONDITIONS NUMBER
C         I4(I)           - NUMBER OF STRUCTURAL CONTRIBUTORS CONSIDERED
C         IADD            - NUMBER OF DATA GROUPS ACCEPTABLE FOR WRITING
C         ICANT           - OPTION CONTROL INTEGER CHECK
C         ICTL            - OPTION CONTROL INTEGER
C         IEXPD           - EXPD  SUBROUTINE SELECTION INTEGER
C         INHIB1(J,I) AND
C         INHIB2(J,I)     - INHIBITOR NAMES
C         IPN             - NUMBER OF EXPERIMENTS
C         J1(K,I)         - SPECIES CONTRIBUTOR CODE NUMBER
C         KODE            - SIGNAL INTEGER FOR ACCEPTABLE DATA
C         NRUN            - RUN NUMBER OF DATA GROUP
C         NRUNT           - RUN NUMBER CHECK
C         O(N)            - EQUIVALENCE RATIOS
C         NUMINH          - NUMBER OF INHIBITORS USED
C         OFSR            - ATOMS OF OXYGEN TO COMPLETELY OXIDIZE ONE
C                                MOLECULE OF FUEL
C         OMX             - EQUIVALENCE RATIO AT MAXIMUM FLAME VELOCITY
C         PM              - ABSOLUTE PRESSURE OF GAS MIXTURE (MM. MERCURY)
C         STDS            - MAXIMUM ALLOWABLE STANDARD DEVIATION OF  U VS
C                                O    CURVE FOR ADDITION TO TAPE
C         O  AND O(N)     - EQUIVALENCE RATIO
C         U  AND U(N)     - FLAME SPEED  (CM./SEC)
C         TEETH           - ACTUAL DISTANCE BETWEEN TEETH TIPS SEEN ON
C                                SCHLIEREN PHOTOGRAPH   (CM.)
C         TM              - MIXTURE TEMPERATURE  (DEG. C)
C         UMX             - MAXIMUM FLAME SPEED  (CM./SEC)
C         USTOC           - FLAME SPEED AT STOICHIOMETRIC CONDITIONS
C                                (CM./SEC)
C         VBFO            - VOLUME PER MOLE OF FUEL.    (CC./GRAM-MOLE)
C         VBM             - VOLUME PER MOLE OF MIXTURE  (CC./GRAM-MOLE)
C         YOX             - MOLE FRACTION OXYGEN IN OXIDANT
C
C
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION  INT(10), DEC(10)
      DIMENSION   A1(20),A2(20),B1(100,20),DA(6,20),I1A(20),I1B(20),
     1            I1C(20),I2(20),I3(20),I4(20),J1(100,20),O(10),U(10)
     2           ,INHIB1(10,20), INHIB2(10,20)
      NIN = 1
   20 IADD = 0
   30 CALL INPUT
      NEX = NEX
      GO TO( 31, 521, 701, 300, 901, 300, 300, 300), NEX
C
C       A CARD ASSIGNMENTS
C
   31 NRUN = J11
      ICTL = INT(1)
      IEXPD = INT(2)
      NUMINH = INT(3)
      MAXON = INT(4)
      IF (NRUN) 32,210,32
   32 IF(NUMINH) 320,320,33
  320 NUMINH =1
C
C       OPTION SELECTION
C
   33 IF (ICTL - 4) 40,150,30
   40 IF (ICTL) 50,30,50
   50 I = IADD + 1
C
C       X  CARD READING
C
   52 READ INPUT TAPE 2, 1002
     9        , A1(I),A2(I),DU,TE ,(INHIB1(J,I),INHIB2(J,I),J=1,
     1NUMINH)
      GO TO 30
C
C       B CARD ASSIGNMENTS
C
  521 NUMCON = IC - 2000
      IF (NUMCON) 523, 522, 523
  522 NRUNT = J11
      ICANT = INT(1)
      I1A(I) = INT(2)
      I1B(I) = INT(3)
      I1C(I) = INT(4)
      I2(I)  = INT(5)
      I3(I)  = INT(6)
      K1     = INT(7)
      DO 5220 K = 2,6
 5220 DA(K,I) = DEC(K-1)
      GO TO 30
  523 IF( NRUNT - J11) 300, 5230, 300
 5230 LIMIT = 10* NUMCON
      IGO = LIMIT - 9
      IF(LIMIT - K1) 525, 525, 524
```

FLAME SPEED CALCULATION EXECUTIVE PROGRAM

```
  524 LIMIT = K1
  525 M = 0
      DO 526 K = IGO, LIMIT
      M = M + 1
      J1(K,I) = INT(M)
  526 B1(K,I) = DEC(M)
      IF( LIMIT - K1)  30, 53, 30
   53 I4(I) = K1
C
C       PRINTOUT OF INPUT DATA
C
      WRITE OUTPUT TAPE 3, 1010
     9          ,NRUN,DU,TE
      WRITE OUTPUT TAPE 3, 1011
      WRITE OUTPUT TAPE 3, 1012
     9          , A1(I), A2(I) ,(INHIB1(J,I), INHIB2(J,I),J=1, NUMINH)
      WRITE OUTPUT TAPE 3, 1013
     9          , I1A(I), I1B(I), I1C(I), I2(I), I3(I)
      WRITE OUTPUT TAPE 3, 10131
     9          ,(DA(K,I),K=2,6)
      WRITE OUTPUT TAPE 3, 1014
      WRITE OUTPUT TAPE 3, 1015
     9          , (J1(K,I),B1(K,I),K=1,K1)
C
C       RUN NUMBER CONSISTENCY CHECK
      IF (NRUN - NRUNT) 200,55,200
C
C       CONTROL INTEGER CHECK
C
   55 IF (ICTL - ICANT) 200,60,200
C
C       OPTION SELECTION
   60 IF (ICTL - 2)  70,70,120
   70 GO TO 30
C
C       C CARD ASSIGNMENTS
C
  701 NRUNT = J11
      ICANT = INT(1)
      IPN   = INT(2)
      TM    = DEC(1)
      PM    = DEC(2)
      OFSR  = DEC(3)
      YOX   = DEC(4)
      VBFO  = DEC(5)
      STOS  = DEC(6)
      TEETH = DEC(7)
   74 WRITE OUTPUT TAPE 3,1017
      WRITE OUTPUT TAPE 3, 1019
     9          , TM,PM,OFSR,YOX,VBFO
C
C       RUN NUMBER CONSISTENCY CHECK
C
      IF (NRUN - NRUNT) 200,71,200
C
C       CONTROL INTEGER CHECK
C
   71 IF (ICTL - ICANT) 200,75,200
   75 VBM = 62366.0*(TM + 273.15)/PM
      CSTOC = 6.0238E23/(VBM*(1.0 + OFSR/(2.0*YOX)))
C
C       EXPERIMENTAL DATA PROCESSING
C
      GO TC (80,90), ICTL
   80 GO TO (82,83,83), IEXPD
   82 CALL EXPD1(NRUN,ICTL,OFSR,YOX,VBFO ,VBM, IPN, O, U, KODE, TEETH ,
     1  NRUNT  )
      GO TC  84
   83 CALL EXPD3(NRUN,ICTL,OFSR,YOX,VBFO ,VBM, IPN, O, U, KODE, TEETH ,
     1  NRUNT  )
   84 IF (KODE -3) 81,100, 81
   90 GO TC 30
C
C       E CARD ASSIGNMENTS
C
  901 NUMCON = IC - 5000
      IF( NUMCON ) 904, 902, 904
  902 NRUNT = J11
      ICANT = INT(1)
      DO 903 N = 1, IPN
  903 O(N) = DEC(N)
      GO TO 30
  904 DO 905 N = 1, IPN
  905 U(N)  = DEC(N)
C
C       RUN NUMBER CONSISTENCY CHECK
C
      IF (NRUN - NRUNT) 200,91,200
C
C       CONTROL INTEGER CHECK
C
   91 IF (ICTL - ICANT) 200,100,200
C
C       DETERMINATION OF MAXIMUM FLAME SPEED
C
  100 CALL MAXM (IPN, O, U, OMX, UMX, USTOC, KODE, STOS, IEXPD, MAXON,
     1             NRUN)
C
C       TEST FOR SUCCESSFUL DETERMINATION OF MAXIMUM FLAME SPEED
C
      IF (KODE - 3) 30,110,30
C
C       TEST FOR REASON FOR UNSUCCESSFUL DETERMINATION OF MAX SPEED
C
   81 IF (KODE - 1) 30,200,30
  110 CMX = 6.0238E23/(VBM*(1.0 + OFSR/(OMX*YOX*2.0)))
```

FLAME SPEED CALCULATION EXECUTIVE PROGRAM

```
C
C      STORAGE OF ACCEPTABLE DATA
C
      DA(2,I) = USTOC
      DA(3,I) = UMX
      DA(4,I) = CSTOC
      DA(5,I) = CMX
      DA(6,I) = OMX
  120 IADD = IADD + 1
C
C      PRINTOUT OF ACCEPTABLE DATA
C
      WRITE OUTPUT TAPE 3, 1020
      WRITE OUTPUT TAPE 3, 1012
     9            , A1(I), A2(I) ,(INHIB1(J,I), INHIB2(J,I),J=1, NUMINH)
      WRITE OUTPUT TAPE 3, 1013
     9            , I1A(I), I1B(I), I1C(I), I2(I), I3(I)
      WRITE OUTPUT TAPE 3, 10131
     9            ,(DA(K,I),K=2,6)
      GO TO 30
C
C      TAPE EDITING AND WRITING
C
  150 CALL TAPE  (NRUN,ICTL,A1,A2,I1A,I1B,I1C,I2,I3,DA,I4,J1,B1,
     1               IADD, DU, TE, LAST)
C
C      TEST FOR COMPLETION OF TAPE EDITING AND WRITING
C
      IF(LAST) 151,20,151
  151 REWIND 8
  210 WRITE OUTPUT TAPE 3, 1030
      GO TO 20
C
C      ERROR PRINT     - RUN NUMBER OR CONTROL INTEGER INCONSISTENCY
C
  200 WRITE OUTPUT TAPE 3, 1016
     9            , NRUN,NRUNT,ICTL,ICANT
      GO TO 30
C
C      DIAGNOSTIC - UNACCEPTABLE CARD ORDER
C
  300 WRITE OUTPUT TAPE 3, 3000, IC, J11
      NIN = 2
      GO TO 30
C
C      FORMAT STATEMENTS
C
 1002 FORMAT ( 12X, 10A6  )
 1010 FORMAT
     9 (1H1,       97HMONSANTO RESEARCH CORPORATION FLAME SPEED CALCULATI
     1ON   -   ROUTINE 201B    MODIFICATION 1  RUN  I4 ,6H DATE 2A6  )
 1011 FORMAT
     9 ( 1H0, 25X,10HINPUT DATA )
 1012 FORMAT
     9 ( 1H0, 30X, 9HFUEL NAME  , 35X,  15HINHIBITORS USED  //
     1  1H0, 30X, 2A6, 32X,2A6 /(1H0, 74X, 2A6))
 1013 FORMAT
     9 (1H0, 10X, 18HFUEL CLASS  NUMBER  3X, I6, 11X ,
     1              18HFUEL GROUP  NUMBER  3X, I6, 11X ,
     2              18HFUEL MEMBER NUMBER  3X, I6,  /
     3  1H0, 10X, 18HDATA SOURCE NUMBER  3X, I6, 11X ,
     4              30HEXPERIMENTAL CONDITIONS NUMBER    3X,I6 )
10131 FORMAT
     9 (1H0, 10X, 52HFLAME VELOCITY AT STOICHIOMETRIC CONCENTRATION RATI
     1O ,  3X, F9.4, 9X,  7HCM./SEC    /
     2  1H0,10X, 22HMAXIMUM FLAME VELOCITY , 33X, F9.4,9X,7HCM./SEC  /
     3  1H0, 10X, 47HFUEL CONCENTRATION AT STOICHIOMETRIC CONDITIONS
     4   10X, E13.6, 3X,  13HMOLECULES/CC.    /
     5  1H0, 10X, 52HFUEL CONCENTRATION AT CONDITIONS OF MAXIMUM VELOCIT
     6Y   5X,E13.6, 3X, 13HMOLECULES/CC.  /
     7 1H0,10X, 40HEQUIVALENCE RATIO AT MAXIMUM FLAME SPEED 16X,F9.5 )
 1014 FORMAT
     9 ( 1H0, 16X,31HSPECIES CONTRIBUTOR CODE NUMBER  ,
     1          17X,43HNUMBER OF CONTRIBUTORS PER MOLECULE OF FUEL  )
 1015 FORMAT
     9 ( 1H , 27X, I6, 49X, F8.3 )
 1016 FORMAT
     9 ( 1H0, 16X,30HDATA OUT OF ORDER - RUN NUMBER   I4,
     1          14X,         20HMISPLACED RUN NUMBER   I4,
     2 / 1H0  16X,22HOPTION CONTROL INTEGER       I4,
     3          22X,21HCONTROL INTEGER CHECK       I4)
 1017 FORMAT
     9 (1H1,  25X, 17HEXPERIMENTAL DATA  / )
 1019 FORMAT
     9 (1H0, 16X, 19HMIXTURE TEMPERATURE  3X, F6.1, 3X, 7HDEG. C.
     1          14X, 16HMIXTURE PRESSURE     3X, F6.1, 3X, 11HMM. MERCURY /
     2  1H0, 16X, 58HATOMS OF OXYGEN TO COMPLETELY OXIDIZE ONE MOLECULE
     3OF FUEL 4X,F6.2 /
     4 1H0, 16X, 31HMOLE FRACTION OXYGEN IN OXIDANT  3X, F7.4 /
     5 1H0, 16X, 23HVOLUME PER MOLE OF FUEL 3X,1PE12.4,3X,17HCC. PER GRA
     6M-MOLE )
 1020 FORMAT
     9 ( 1H1, 25X,15HDATA ACCEPTABLE    )
 1030 FORMAT ( 1H1, 10X, 23HCOMPUTATIONS COMPLETED        )
 3000 FORMAT( 1H0, 25X,  41HDATA CARD ORDER INCORRECT - CARD NUMBER
     1       I4, 5X, 12HRUN NUMBER   I5   )
      END
```

SUBROUTINE EXPD1

EXPERIMENTAL FLAME SPEED DATA REDUCTION

```
CXPD1 EXPD1 SUBROUTINE  MOD 0  MARCH 1, 1962    MRC-DAYTON
C
C       NOMENCLATURE
C
C       AR                  - CUMULATIVE CONE AREA *2/PI
C       A(N)                - TOTAL CONE AREA  (SQUARE CM.)
C       D(K)                - CONE DIAMETER AT ABOVE ELEVATION (CM.)
C       DA(K)               - MEASURED DIAMETER AT ABOVE ELEVATION
C       DELS                - INCREMENT SLANT HEIGHT (CM.)
C       ELA                 - REFERENCE LENGTH MEASURED IN UNITS OF DA(K)
C       ELCM                - REFERENCE LENGTH MEASURED IN CM.
C       FMI(N)              - MOLE FRACTION OF INHIBITOR IN MIXTURE
C       H(K)                - ELEVATION ABOVE BURNER TOP (CM.)
C       HPKA                - MEASURED PEAK HEIGHT
C       ICANT               - OPTION CONTROL INTEGER CHECK
C       IH(K)               - MEASURED ELEVATION ABOVE BURNER TOP
C       IPK                 - TOTAL NUMBER OF CONE MEASUREMENTS
C       IPN                 - NUMBER OF EXPERIMENTS
C       IRK                 - NUMBER OF DIAMETER MEASUREMENTS PER RUN
C       KODE                - SIGNAL INTEGER FOR ACCEPTABLE DATA
C       NRUN                - RUN NUMBER OF DATA GROUP
C       NRUNT               - RUN NUMBER CHECK
C       O AND O(N)          - EQUIVALENCE RATIO
C       OFSR                - ATOMS OF OXYGEN TO COMPLETELY OXIDIZE ONE
C                                   MOLECULE OF FUEL
C       QFO(N)              - FUEL FLOW (CC./SEC AT VBFO MOLAL VOLUME)
C       QM(N)               - VOLUME FLOW OF MIXTURE  (CC./SEC AT ACTUAL
C                                   TEMPERATURE AND PRESSURE)
C       QXO(N)              - OXIDANT FLOW (CC./SEC AT 0 DEG. C, 760 MM. HG)
C       SF                  - SCALE FACTOR  (CM./UNITS OF DA(K))
C       TEETH               - ACTUAL DISTANCE BETWEEN TEETH TIPS SEEN ON
C                                   SCHLIEREN PHOTOGRAPH  (CM.)
C       U AND U(N)          - FLAME SPEED  (CM./SEC)
C       VBFO                - VOLUME PER MOLE OF FUEL     (CC./GRAM-MOLE)
C       VBM                 - VOLUME PER MOLE OF MIXTURE  (CC./GRAM-MOLE)
C       WF                  - FUEL FLOW      (GRAM-MOLES/SEC.)
C       WX                  - OXIDANT FLOW  (GRAM-MOLES/SEC.)
C       YOX                 - MOLE FRACTION OXYGEN IN OXIDENT
C
      SUBROUTINE EXPD1(NRUN,ICTL,OFSR,YOX,VBFO,VBM,IPN,O,U,KODE,TEETH,
     1   NRUNT  )
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION  INT(10), DEC(10)
      DIMENSION A(100), D(100), DA(100), H(100), IH(100), FMI(15)
     1          ,O(15) , QFO(15) , QM(15), QXO(15), U(15)
      WRITE OUTPUT TAPE 3, 1010
      L = 0
      KODE = 3
      DO 100 N=1,IPN
   10 CALL INPUT
      NEX = NEX
      IF( NEX - 4) 200, 11, 200
   11 NUMCON = IC - 4000
      IF( NUMCON ) 13, 12, 13
C
C       D CARD ASSIGNMENTS
C
   12 NRUNT = J11
      ICANT = INT(1)
      IRK   = INT(2)
      QFO(N) = DEC(1)
      QXO(N) = DEC(2)
      FMI(N) = DEC(3)
      HPKA   = DEC(4)
      ELCM   = DEC(5)
      ELA    = DEC(6)
      GO TO 10
   13 IF( NRUNT - J11) 200, 141, 200
  141 LIMIT = 10* NUMCON
      IGO   = LIMIT - 9
      IF( LIMIT - IRK  ) 142, 142, 140
  140 LIMIT = IRK
  142 M = 0
      DO 143 K = IGO, LIMIT
      M = M + 1
      IH(K) = INT(M)
  143 DA(K) = DEC(M)
      IF( LIMIT - IRK ) 10, 144, 10
  144 IF(TEETH)14,15,14
   15 TEETH =0.2
   14 SF    = ELCM /ELA
      IPK   = IRK + 1
C
C       TEST FOR MORE THAN ONE HUNDRED MEASUREMENTS
C
      IF(IPK-100)19,19,30
   19 DO 20 K= 1 , IRK
      H(K) = TEETH *FLOATF(IH(K)-1)
   20   D(K) = DA(K)*SF
C
C       CALCULATION OF PEAK HEIGHT IN CM.
C
      H(IPK) = HPKA * SF
      D(IPK) = 0.0
      JPK1 = 1
C
C       PRINTOUT OF FLAME FRONT DIMENSIONS
C
C       TEST FOR MORE THAN TEN MEASUREMENTS
C
      IF(IPK-10) 24,24,21
   21 DO 23 JPK=10,IPK,10
      IF(L-48)230,230,231
  231 WRITE OUTPUT TAPE 3, 1020
      L=0
C
```

EXPERIMENTAL FLAME SPEED DATA REDUCTION

```
C       PRINTOUT FOR GROUPS OF TEN MEASUREMENTS
C
  230 WRITE OUTPUT TAPE 3, 10121,
     9                  N         , (IH(K),K= JPK1, JPK  )
      WRITE OUTPUT TAPE 3, 1013,
     9                   (DA(K),K= JPK1 , JPK )
      WRITE OUTPUT TAPE 3, 1014,
     9                   (H(K) ,K= JPK1 , JPK  )
      WRITE OUTPUT TAPE 3, 1015,
     9                   (D(K) ,K= JPK1 , JPK )
      JPK1 =JPK  + 1
   23 L= L+ 8
   24 JRK  =IPK-1
      IF(L-48)25,25,241
  241 WRITE OUTPUT TAPE 3, 1020
      L=0
C
C       PRINTOUT FOR LESS THAN TEN MEASUREMENTS
C
   25 WRITE OUTPUT TAPE 3, 10121,
     9                  N         , (IH(K),K= JPK1, JRK  )
      WRITE OUTPUT TAPE 3, 1013,
     9                   (DA(K),K= JPK1 , JRK )
      WRITE OUTPUT TAPE 3, 1014,
     9                   (H(K) ,K= JPK1 , IPK  )
      WRITE OUTPUT TAPE 3, 1015,
     9                   (D(K) ,K= JPK1 , IPK )
      WRITE OUTPUT TAPE 3, 10151,
     9                  SF
      L = L + 8
C
C       RUN NUMBER CONSISTENCY CHECK
C
       IF (NRUN - NRUNT) 30,31,30
   30  KODE = 1
      IRUNT  = NRUNT
      GO TO 100
C
C       CONTROL INTEGER CHECK
C
   31  IF (ICTL - ICANT) 30,35,30
C
C       CALCULATION OF OXIDANT AND FUEL FLOW
C
   35  WX = QXO(N)/22414.0
       WF = QFO(N)/VBFO
      QM(N) = (WF + WX) * VBM /(1.0 - FMI(N))
C
C       CALCULATION OF EQUIVALENCE RATIO
C
       O(N) = WF*OFSR/(2.0*WX*YOX)
      IRK =IPK-1
C
C       CALCULATION OF CONE AREA
C
      AR = 0.0
      DO 40 K=1, IRK
       DELS = SQRTF((H(K+1) - H(K))**2 + ((D(K) - D(K+1))/2.0)**2)
   40  AR = AR + (D(K) + D(K+1))*DELS
      A(N) = 1.570796*AR
C
C       CALCULATION OF FLAME SPEED
C
      U(N) = QM(N)/A(N)
  100 CONTINUE
      IF(L+IPN -56) 101,101,102
  102 WRITE OUTPUT TAPE 3, 1018
      L = 0
C
C       PRINTOUT OF FLAME SPEED
C
  101 WRITE OUTPUT TAPE 3, 1016
      DO 110 N=1,IPN
  110 WRITE OUTPUT TAPE 3, 1017
     9                  ,N, QFO(N), QXO(N), FMI(N), QM(N), A(N), U(N), O(N)
      NRUNT  =  IRUNT
  120 RETURN
C
C       DIAGNOSTIC - UNACCEPTABLE CARD ORDER
C
  200 NEX = 2
      WRITE OUTPUT TAPE 3, 3000, IC, J11
      KODE = 1
      GO TO 120
C
C       FORMAT STATEMENTS
C
 1010 FORMAT
     9 (1HO, 10X, 22HFLAME FRONT DIMENSIONS   / 1HO, 4H SET    )
10121 FORMAT
     9 (1HO, I4, 2X,          19HSTATION  (MEASURED) ,4X, 10I9 )
 1013 FORMAT
     9 (1H ,      6X,  19HDIAMETER (MEASURED), 4X, 10F 9.3 )
 1014 FORMAT
     9 (1H ,      6X,  14HHEIGHT    (CM.)  ,     9X, 10F 9.5 )
 1015 FORMAT
     9 (1H ,      6X,  14HDIAMETER (CM.)  ,     9X, 10F 9.5 )
10151 FORMAT
     9 (1H , 6X, 12HSCALE FACTOR   3X, F 10.5   )
 1016 FORMAT
     9 (1HO, 4H SET, 7X,  9HFUEL FLOW , 4X, 12HOXIDANT FLOW , 3X,
     1 13HMOLE FRACTION , 5X,  11HVOLUME FLOW , 7X,  9HCONE AREA ,
     2 5X, 11HFLAME SPEED , 5X, 11HEQUIVALENCE       /
     3  1H , 11X, 9H(CC./SEC), 6X, 9H(CC./SEC) , 6X, 9HINHIBITOR ,
     4  8X ,  9H(CC./SEC), 8X,  9H(SQ. CM.) , 6X, 9H(CM./SEC) ,
     5  9X ,  5HRATIO  )
```

EXPERIMENTAL FLAME SPEED DATA REDUCTION

```
1017 FORMAT                                                        EXPD1  213
    9 (1H , I4, 6X,F10.5,6X,F10.5,6X,F10.5,6X,F10.5,6X,F10.5,6X,F10.5,  EXPD1  214
    1 6X,F1'.5)                                                    EXPD1  215
1018 FORMAT                                                        EXPD1  216
    9 (1H1)                                                        EXPD1  217
1020 FORMAT                                                        EXPD1  218
    9 (1H1, 10X, 22HFLAME FRONT DIMENSIONS  /1H0 , 4H RUN )        EXPD1  219
3000 FORMAT( 1H0, 25X,  41HDATA CARD ORDER INCORRECT - CARD NUMBER  EXPD1  220
    1     I4, 5X, 12HRUN NUMBER     I5    )                        EXPD1  221
     END                                                           EXPD1  222
```

SUBROUTINE EXPD3

EXPERIMENTAL FLAME SPEED DATA REDUCTION

```
CEXPD3   EXPD3 SUBROUTINE MOD1 SEPT 8, 1962   MRC  DAYTON
C
C      NOMENCLATURE
C
C      AR                  - CUMULATIVE CONE AREA *2/PI
C      A(N)                - TOTAL CONE AREA  (SQ. CM.)
C      D(K)                - CONE DIAMETER AT ABOVE ELEVATION (CM.)
C      DA(K)               - MEASURED DIAMETER AT ABOVE ELEVATION
C      DELS                - INCREMENT SLANT HEIGHT (CM.)
C      ELA                 - REFERENCE LENGTH MEASURED IN UNITS OF DA(K)
C      ELCM                - REFERENCE LENGTH MEASURED IN CM.
C      FMI(N)              - MOLE FRACTION OF INHIBITOR IN MIXTURE
C      H(K)                - ELEVATION ABOVE BURNER TOP (CM.)
C      HPKA                - MEASURED PEAK HEIGHT
C      ICANT               - OPTION CONTROL INTEGER CHECK
C      IH(K)               - MEASURED ELEVATION ABOVE BURNER TOP
C      IPK                 - TOTAL NUMBER OF CONE MEASUREMENTS
C      IPN                 - NUMBER OF EXPERIMENTS
C      IRK                 - NUMBER OF DIAMETER MEASUREMENTS PER RUN
C      JPK, JPK1, N, K,    - COUNTING INTEGERS
C      KODE                - SIGNAL INTEGER FOR ACCEPTABLE DATA
C      NRUN                - RUN NUMBER OF DATA GROUP
C      NRUNT               - RUN NUMBER CHECK
C      O AND O(N)          - EQUIVALENCE RATIO
C      OFSR                - ATOMS OF OXYGEN TO COMPLETELY OXIDIZE ONE
C                                 MOLECULE OF FUEL
C      QFO(N)              - FUEL FLOW (CC./SEC AT VBFO MOLAL VOLUME)
C      QM(N)               - VOLUME FLOW OF MIXTURE  (CC./SEC AT ACTUAL
C                                 TEMPERATURE AND PRESSURE)
C      QXO(N)              - OXIDANT FLOW (CC./SEC AT 0 DEG. C, 760 MM. HG)
C      SF                  - SCALE FACTOR  (CM./UNITS OF DA(K))
C      TEETH               - ACTUAL DISTANCE BETWEEN TEETH TIPS SEEN ON
C                                 SCHLIEREN PHOTOGRAPH   (CM.)
C      U AND U(N)          - FLAME SPEED  (CM./SEC)
C      VBFO                - VOLUME PER MOLE OF FUEL      (CC./GRAM-MOLE)
C      VBM                 - VOLUME PER MOLE OF MIXTURE   (CC./GRAM-MOLE)
C      WF                  - FUEL FLOW      (GRAM-MOLES/SEC.)
C      WX                  - OXIDANT FLOW   (GRAM-MOLES/SEC.)
C      YOX                 - MOLE FRACTION OXYGEN IN OXIDENT
C
      SUBROUTINE EXPD3(NRUN,ICTL,OFSR,YOX,VBFO,VBM,IPN,O,U,KODE,TEETH,
     1   NRUNT  )
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION  INT(10), DEC(10)
      DIMENSION A(100), D(100), DA(100), H(100), IH(100), FMI(15)
     1         ,O(15) , QFO(15) , QM(15), QXO(15), U(15)
      WRITE OUTPUT TAPE 3, 1010
      L=0
      KODE = 3
      DO 100 N=1,IPN
   10 CALL INPUT
      NEX = NEX
      IF( NEX - 4) 200, 11, 200
   11 NUMCON = IC - 4000
      IF( NUMCON ) 13, 12, 13
C
C       D CARD ASSIGNMENTS
C
   12 NRUNT = J11
      ICANT = INT(1)
      IRK   = INT(2)
      QFO(N) = DEC(1)
      QXO(N) = DEC(2)
      FMI(N) = DEC(3)
      HPKA   = DEC(4)
      ELCM   = DEC(5)
      ELA    = DEC(6)
      GO TO 10
   13 IF( NRUNT - J11) 200, 141, 200
  141 LIMIT = 10* NUMCON
      IGO   = LIMIT - 9
      IF( LIMIT - IRK  ) 142, 142, 140
  140 LIMIT = IRK
  142 M = 0
      DO 143 K = IGO, LIMIT
      M = M + 1
      IH(K) = INT(M)
  143 DA(K) = DEC(M)
      IF( LIMIT - IRK ) 10, 144, 10
  144 IRUN =NRUN  + N -1
      IF(TEETH)14,15,14
   15 TEETH =0.2
   14 SF    = ELCM /ELA
      IPK   = IRK + 1
C
C       TEST FOR MORE THAN ONE HUNDRED MEASUREMENTS
C
      IF(IPK-100)19,19,30
   19 DO 20 K= 1 , IRK
      H(K) = TEETH *FLOATF(IH(K)-1)
   20   D(K) = DA(K)*SF
C
C       CALCULATION OF PEAK HEIGHT IN CM.
C
      H(IPK) = HPKA * SF
      D(IPK) = 0.0
      JPK1 = 1
C
C       PRINTOUT OF FLAME FRONT DIMENSIONS
C
C       TEST FOR MORE THAN TEN MEASUREMENTS
C
      IF(IPK-10) 24,24,21
   21 DO 23 JPK=10,IPK,10
      IF(L-48)230,230,231
  231 WRITE OUTPUT TAPE 3, 1020
```

EXPERIMENTAL FLAME SPEED DATA REDUCTION

```
      L=0
C
C       PRINTOUT FOR GROUPS OF TEN MEASUREMENTS
C
  230 WRITE OUTPUT TAPE 3, 10121,
     9              IRUN,       (IH(K), K= JPK1, JPK )
      WRITE OUTPUT TAPE 3, 1013,
     9              (DA(K),K= JPK1, JPK )
      WRITE OUTPUT TAPE 3, 1014,
     9              (H(K), K= JPK1, JPK )
      WRITE OUTPUT TAPE 3, 1015,
     9              (D(K), K= JPK1, JPK )
      JPK1 =JPK   + 1
   23 L= L+ 8
   24 IF(L-48)25,25,241
  241 WRITE OUTPUT TAPE 3, 1020
      L=0
C
C       PRINTOUT FOR LESS THAN TEN MEASUREMENTS
C
   25 WRITE OUTPUT TAPE 3, 1012,
     9              IRUN, HPKA, (IH(K), K= JPK1, IRK  )
      WRITE OUTPUT TAPE 3, 1013,
     9              (DA(K), K= JPK1, IRK  )
      WRITE OUTPUT TAPE 3, 1014,
     9              (H(K), K= JPK1, IPK )
      WRITE OUTPUT TAPE 3, 1015,
     9              (D(K), K= JPK1, IPK )
      WRITE OUTPUT TAPE 3, 10151,
     9               ELCM, ELA
      L= L+10
C
C       RUN NUMBER CONSISTENCY CHECK
C
       IF (IRUN - NRUNT) 30,31,30
   30  KODE = 1
      IRUNT  = NRUNT
       GO TO 100
C
C       CONTROL INTEGER CHECK
C
   31  IF (ICTL - ICANT) 30,35,30
C
C       CALCULATION OF OXIDANT AND FUEL FLOW
C
   35  WX = QXO(N)/22414.0
       WF = QFO(N)/VBFO
      QM(N) = (WF + WX) * VBM /(1.0 - FMI(N))
C
C       CALCULATION OF EQUIVALENCE RATIO
C
       D(N) = WF*OFSR/(2.0*WX*YOX)
C
C       CALCULATION OF CONE AREA
C
      AR = 0.0
      DO 40  K = 1, IRK
       DELS = SQRTF((H(K+1) - H(K))**2 + ((D(K) - D(K+1))/2.0)**2)
   40  AR = AR + (D(K) + D(K+1))*DELS
      A(N) = 1.570796*AR
C
C       CALCULATION OF FLAME SPEED
C
      U(N) = QM(N)/A(N)
  100 CONTINUE
      IF(L+IPN -56) 101,101,102
  102 WRITE OUTPUT TAPE 3, 1018
      L=0
C
C       PRINTOUT OF FLAME SPEED
C
  101 WRITE OUTPUT TAPE 3, 1016
      DO 110 N=1,IPN
      IRUN = NRUN -1 +N
  110 WRITE OUTPUT TAPE 3, 1017,
     9              IRUN, QFO(N), QXO(N), FMI(N), QM(N), A(N), U(N), D(N)
      NRUNT  =  IRUNT
  120 RETURN
C
C       DIAGNOSTIC - UNACCEPTABLE CARD ORDER
C
  200 NEX = 2
      WRITE OUTPUT TAPE 3, 3000, IC, J11
      KODE = 1
      GO TO 120
C
C       FORMAT STATEMENTS
C
 1010 FORMAT
     9 (1H0, 10X, 22HFLAME FRONT DIMENSIONS /1H0, 4H RUN )
 1012 FORMAT
     9 (1H0, I4, 2X,  28HPEAK HEIGHT (MEASURED UNITS)  F8.2 /
     1  1H ,      6X,  19HSTATION  (MEASURED), 4X, 10I9)
10121 FORMAT
     9 (1H0, I4, 2X,  19HSTATION  (MEASURED), 4X, 10I9)
 1013 FORMAT
     9 (1H ,      6X,  19HDIAMETER (MEASURED), 4X, 10F 9.3 )
 1014 FORMAT
     9 (1H ,      6X,  14HHEIGHT   (CM.)  ,    9X, 10F 9.5 )
 1015 FORMAT
     9 (1H ,      6X,  14HDIAMETER (CM.)  ,    9X, 10F 9.5 )
10151 FORMAT
     9 (1H , 6X, 26HACTUAL LENGTH OF REFERENCE 3X,F10.5,3X, 3HCM.
     1      7X, 28HMEASURED LENGTH OF REFERENCE 3X,F10.5,8H   UNITS )
 1016 FORMAT
     9 (1H0, 4H RUN, 7X,  9HFUEL FLOW , 4X, 12HOXIDANT FLOW , 3X,
```

```
     1 13HMOLE FRACTION , 5X,  11HVOLUME FLOW , 7X,  9HCONE AREA ,           EXPD3    213
     2 5X, 11HFLAME SPEED , 5X, 11HEQUIVALENCE      /                        EXPD3    214
     3  1H , 11X, 9H(CC./SEC), 6X, 9H(CC./SEC) , 6X, 9HINHIBITOR ,           EXPD3    215
     4  8X ,  9H(CC./SEC), 8X,  9H(SQ. CM.) , 6X, 9H(CM./SEC) ,              EXPD3    216
     5  9X ,  5HRATIO  )                                                     EXPD3    217
 1017 FORMAT                                                                 EXPD3    218
     9 (1H , I4, 6X,F10.5,6X,F10.5,6X,F10.5,6X,F10.5,6X,F10.5,6X,F10.5,      EXPD3    219
     1 6X,F10.5)                                                             EXPD3    220
 1018 FORMAT                                                                 EXPD3    221
     9 (1H1)                                                                 EXPD3    222
 1020 FORMAT                                                                 EXPD3    223
     9 (1H1, 10X, 22HFLAME FRONT DIMENSIONS  /1H0 , 4H RUN )                 EXPD3    224
 3000 FORMAT( 1H0, 25X,  41HDATA CARD ORDER INCORRECT - CARD NUMBER          EXPD3    225
     1       I4, 5X, 12HRUN NUMBER    I5   )                                 EXPD3    226
      END                                                                    EXPD3    227
```

SUBROUTINE MAXM

MAXIMUM FLAME SPEED DETERMINATION

```
CMAXM  SUBROUTINE MAXM FOR ROUTINE 2018 FEB 28 1962  MRC  -  DAYTON
C
C      NOMENCLATURE
C
C      A(K)                  - COEFFICIENTS OF FITTED EQUATION
C      ARG                   - ARGUMENT OF QUADRATIC SQUARE ROOT
C      G(J,K)                - SUM OF SQUARES AND CROSS PRODUCTS OF THE
C                                 X(N,K) MATRIX
C      IPN                   - NUMBER OF DATA POINTS
C      J, K, L, N            - INDICIES
C      K9                    - SIGNAL FLAG FOR SEQUENCE OF CALCULATIONS
C      KODE                  - SIGNAL INTEGER FOR ACCEPTABLE DATA
C      MAXON                 - SWITCH TO BYPASS MAXM SUBROUTINE
C                                (ANY NON-ZERO VALUE BYPASSES SUBROUTINE)
C      NCF                   - NUMBER OF COEFFICIENTS
C      O(N)                  - EQUIVALENCE RATIO
C      OH                    - LARGEST EQUIVALENCE RATIO IN SET
C      OINF                  - EQUIVALENCE RATIO AT INFLECTION POINT OF CUBIC
C                                 CURVE
C      OL                    - SMALLEST EQUIVALENCE RATIO IN SET
C      OMX                   - EQUIVALENCE RATIO AT MAXIMUM FLAME VELOCITY
C      STDS                  - MAXIMUM ALLOWABLE STANDARD DEVIATION OF U VS
C                                 O    CURVE FOR ADDITION TO TAPE
C      SUM                   - SUM OF THE SQUARES OF THE DEVIATIONS
C      U(N)                  - FLAME SPEED  (CM./SEC)
C      UD(N)                 - DEVIATION BETWEEN MEASURED AND PREDICTED
C                               FLAME SPEED  (CM./SEC)
C      UDP(N)                - PERCENT DEVIATION BETWEEN MEASURED AND
C                               PREDICTED FLAME SPEED
C      UMX                   - MAXIMUM FLAME SPEED  (CM./SEC)
C      UP(N)                 - PREDICTED FLAME SPEED (CM./SEC)
C      USTD                  - STANDARD DEVIATION OF FLAME SPEED (CM./SEC)
C      USTOC                 - FLAME SPEED AT STOICHIMETRIC CONDITIONS
C                                 (CM./SEC)
C      X(N,K)                - INDEPENDENT VARIABLES
      SUBROUTINE MAXM( IPN, O, U, OMX, UMX, USTOC, KODE, STDS,
     1                 IEXPD, MAXON, NRUN )
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION  INT(10), DEC(10)
      DIMENSION A(10),G(10,11),O(10),U(10),UD(10),UDP(10),UP(10),X(10,1
     1)
      KODE = 0
      IF(MAXON) 500, 20, 500
   20 WRITE OUTPUT TAPE 3, 1001
      IF (IPN - 2) 500,500,25
   25 OL = O(1)
      OH = OL
      DO 30 N=1,IPN
      OL = MIN1F(OL,O(N))
      OH = MAX1F(OH,O(N))
C
C      FORMATION OF COEFFICIENT MATRIX
C
      X(N,1) = 1.0
      X(N,2) = O(N)
      X(N,3) = O(N)**2
      X(N,4) = O(N)**3
   30 X(N,5) = U(N)
C
C      TEST FOR MORE THAN FOUR DATA POINTS
C
      IF (IPN - 4) 150,40,50
C
C      ATTEMPT TO FIT FOUR DATA POINTS TO A FOUR CONSTANT EQUATION
C
C      SOLUTION OF FOUR EQUATIONS IN FOUR UNKNOWNS
C
   40 CALL CROUT  (4,X,A)
C
C      TEST FOR UNSUCCESSFUL SOLUTION
C
      IF ( SENSE LIGHT 3) 41, 70
C
C      PRINTOUT OF UNSUCCESSFUL FIT
C
   41 WRITE OUTPUT TAPE 3, 1010
      WRITE OUTPUT TAPE 3, 1011,
     9               ((X(K,L),L=1,5 ),K=1,4)
      GO TO 200
C
C      ATTEMPT TO FIT FOUR OR MORE DATA POINTS TO A FOUR CONSTANT
C         EQUATION
C
   50 DO 60 J=1,4
      DO 60 K=1,5
      G(J,K) = 0.0
      DO 60 N=1,IPN
C
C      GENERATION OF FOUR REGRESSION EQUATIONS
C
   60 G(J,K) = G(J,K) + X(N,J)*X(N,K)
C
C      SOLUTION OF FOUR REGRESSION EQUATIONS IN FOUR UNKNOWNS
C
      CALL CROUT (4,G,A)
      IF( SENSE LIGHT 3) 61, 70
C
C      PRINTOUT OF UNSUCCESSFUL FIT
C
   61 WRITE OUTPUT TAPE 3, 1010
      WRITE OUTPUT TAPE 3, 1011,
     9               ((G(K,L),L=1,5 ),K=1,4)
      GO TO 200
C
C      OPERATIONS ON FOUR OR MORE DATA POINTS
C
```

MAXIMUM FLAME SPEED DETERMINATION

```
   70 NCF = 4
      K9 = 1
      IF DIVIDE CHECK 71, 71
   71 UMX = 0.0
      OMX = 0.0
      OINF = -A(3)/(3.0*A(4))
      IF DIVIDE CHECK 310, 75
   75 K9 = 2
      ARG = 1.0 - 3.0*A(2)*A(4)/A(3)**2
      IF DIVIDE CHECK 310, 80
C
C       TEST FOR SQUARE ROOT OF NEGATIVE NUMBER
C
   80 IF (ARG) 310,310,85
   85 K9 = 3
C
C       DETERMINATION OF EQUIVALENCE RATIO AT MAXIMUM FLAME SPEED
C
      OMX = OINF*(1.0 + SIGNF(SQRTF(ARG),A(3)))
C
C       TEST TO SEE IF EQUIVALENCE RATIO AT MAXIMUM FLAME SPEED IS WITHIN
C             DATA RANGE
C
      IF (OMX - OH) 90,90,300
   90 IF (OL - OMX) 95,95,300
   95 K9 = 4
      OMIN = OINF * (1.0 - SIGNF(SQRTF(ARG),A(3)))
C
C       TEST FOR MINIMUM POINT IN DATA RANGE
C
      IF(OMIN - OH) 100,110,110
  100 IF(OL - OMIN) 300,110,110
  110 K9 = 7
      GO TO 300
C
C       END OF OPERATION ON CUBIC FIT
C
C       ATTEMPT TO FIT THREE DATA POINTS TO A THREE CONSTANT EQUATION
C
  150 DO 160 N=1,IPN
  160 X(N,4) = U(N)
      CALL CROUT  (3,X,A)
      IF( SENSE LIGHT 3) 161, 230
C
C       PRINTOUT OF UNSUCCESSFUL FIT
C
  161 WRITE OUTPUT TAPE 3, 1012
      WRITE OUTPUT TAPE 3, 1013,
     9              ((X(K,L),L=1,4),K=1,3)
      GO TO 500
C
C       ATTEMPT TO FIT FOUR OR MORE DATA POINTS TO A THREE CONSTANT
C             EQUATION
C
  200 DO 210 N=1,IPN
  210 X(N,4) = U(N)
      DO 220 J=1,3
      DO 220 K=1,4
      G(J,K) = 0.0
      DO 220 N=1,IPN
C
C       GENERATION OF THREE REGRESSION EQUATIONS
C
  220 G(J,K) = G(J,K) + X(N,J)*X(N,K)
C
C       SOLUTION OF THREE EQUATIONS IN THREE UNKNOWNS
C
      CALL CROUT (3,G,A)
C
C       TEST FOR UNSUCCESSFUL SOLUTION
C
      IF(SENSE LIGHT 3 ) 221, 230
C
C       PRINTOUT OF UNSUCCESSFUL FIT
C
  221 WRITE OUTPUT TAPE 3, 1012
      WRITE OUTPUT TAPE 3, 1013,
     9              ((G(K,L),L=1,4),K=1,3)
      GO TO 500
C
C       OPERATIONS ON THREE OR MORE DATA POINTS
C
  230 NCF = 3
      K9 = 5
      A(4) = 0.0
      UMX = 0.0
      OMX = 0.0
      IF (A(3)) 240,310,310
  240 K9 = 6
C
C       DETERMINATION OF EQUIVALENCE RATIO AT MAXIMUM FLAME SPEED
C
      OMX = -A(2)/(2.0*A(3))
C
C       TEST TO SEE IF EQUIVALENCE RATIO AT MAXIMUM FLAME SPEED IS WITHIN
C             DATA RANGE
C
      IF (OMX - OH) 250,250,300
  250 IF (OL - OMX) 260,260,300
C
C       END OF OPERATION ON PARABOLIC FIT
C
C       OPERATION ON DATA AFTER SUCCESSFUL FIT
C
  260 K9 = 7
C
```

MAXIMUM FLAME SPEED DETERMINATION

```
C      CALCULATION OF MAXIMUM FLAME SPEED
C
  300 UMX = A(1) + OMX*(A(2) + OMX*(A(3) + OMX*A(4)))
C
C       CALCULATION OF FLAME SPEED AT AN EQUIVALENCE RATIO OF ONE
C
  310 USTOC = A(1) + A(2) + A(3) + A(4)
      SUM = 0.0
      DO 320 N=1,IPN
      UP(N) = A(1) + D(N)*(A(2) + D(N)*(A(3) + D(N)*A(4)))
C
C       COMPARISON  OF PREDICTED VS. MEASURED EQUIVALENCE RATIOS
C
      UD(N) = U(N) - UP(N)
C
C       CALCULATION OF THE PERCENT ERROR OF THE DEVIATION
C
      UDP(N) = 100.0*UD(N)/UP(N)
C
C       SUMMATION OF THE SQUARE OF THE DEVIATIONS
C
  320 SUM = SUM + UD(N)**2
      IF (IPN - NCF) 330,330,340
  330 USTD = 0.0
      GO TO 350
C
C       CALCULATION OF STANDARD DEVIATION OF FLAME SPEED
C
  340 USTD = SQRTF(SUM/FLOATF(IPN-NCF))
  350 WRITE OUTPUT TAPE 3, 1014
      WRITE OUTPUT TAPE 3, 1015
      WRITE OUTPUT TAPE 3, 1016,
     9          (A(K),K=1,4),USTD,OMX,UMX
      IF(IEXPD - 1) 351,352,351
  351 WRITE OUTPUT TAPE 3, 10171
      DO 354 N=1, IPN
      IRUN = NRUN + N -1
  354 WRITE OUTPUT TAPE 3, 1018
     9          , IRUN, D(N), U(N), UP(N), UD(N), UDP(N)
      GO TO 353
  352 WRITE OUTPUT TAPE 3, 1017
      DO 3521  N = 1, IPN
 3521 WRITE OUTPUT TAPE 3, 1018
     9          ,   N , D(N), U(N), UP(N), UD(N), UDP(N)
  353 IF(K9-4) 360,360,370
C
C       ERROR PRINT   - CUBIC FIT OF CURVE UNSATISFACTORY
C
  360 WRITE OUTPUT TAPE 3, 1019
      GO TO (361,362,363,364), K9
C
C       DIAGNOSTIC     - PARABOLIC FIT INDICATED , A3 SMALL OR ZEPO
C
  361 WRITE OUTPUT TAPE 3, 1020
      GO TO 200
C
C       ERROR PRINT   - NO MAXIMUM
C
  362 WRITE OUTPUT TAPE 3, 1021
      GO TO 200
C
C       ERROR PRINT   - MAXIMUM OUTSIDE DATA RANGE
C
  363 WRITE OUTPUT TAPE 3, 1022
      GO TO 200
C
C       ERROR PRINT   - MINIMUM POINT IN DATA RANGE
C
  364 WRITE OUTPUT TAPE 3, 1023
      GO TO 200
  370 IF (K9 - 7) 371,380,500
C
C       ERROR PRINT   - PARABOLIC FIT OF CURVE UNSATISFACTORY
C
  371 WRITE OUTPUT TAPE 3, 1024
      IF (K9 - 6) 372,373,500
  372 WRITE OUTPUT TAPE 3, 1021
      GO TO 500
  373 WRITE OUTPUT TAPE 3, 1022
      GO TO 500
  380 IF (STDS) 381,381,382
  381 STDS = 1.0
C
C       TEST TO SEE IF STANDARD DEVIATION WITHIN SPECIFIED RANGE
C
  382 IF (USTD - STDS) 400,400,383
C
C       ERROR PRINT   - STANDARD DEVIATION TOO HIGH
C
  383 WRITE OUTPUT TAPE 3, 1025,
     9          STDS
      GO TO 500
  400 KODE = 3
  500 RETURN
C
C       FORMAT STATEMENTS
C
 1001 FORMAT
     9 (1H1)
 1011 FORMAT
     9 (1H ,  10X, E12.5, 10X, E12.5,10X, E12.5,10X, E12.5,10X,E12.5 )
 1012 FORMAT
     9 (1H0,  10X, 73HPARABOLIC FIT OF FLAME SPEED CURVE FAILED - MATRIX
     1 OF THE COEFFICIENTS IS   /
     2   1H0, 10X, 12HEQUIV. RATIO , 8X, 16HEQUIV. RATIO **2,  9X,
     3          11HFLAME SPEED //)
```

MAXIMUM FLAME SPEED DETERMINATION

```
 1013 FORMAT
     9 (1H ,  10X, E12.5, 10X, E12.5,10X, E12.5,10X, E12.5)
 1014 FORMAT
     9 (1H0,  10X, 22HFLAME SPEED CURVE DATA  )
 1016 FORMAT
     9 (1H ,   6X, 4(4X, 1PE12.4),  5X,  0PF8.4 , 8X,F9.5, 9X,F9.4 )
 1017 FORMAT
     9 (1H0, 10X,   8HDATA SET ,10X,11HEQUIVALENCE  10X, 8HMEASURED
     1        11X,   9HPREDICTED 10X, 9HDEVIATION    11X, 7HPERCENT  /
     2  1H    31X,   5HRATIO     12X,11HFLAME SPEED   8X,11HFLAME SPEED
     3        28X,   9HDEVIATION /)
10171 FORMAT
     9 (1H0, 10X,   8H      RUN ,10X,11HEQUIVALENCE  10X, 8HMEASURED
     1        11X,   9HPREDICTED 10X, 9HDEVIATION    11X, 7HPERCENT  /
     2  1H    31X,   5HRATIO     12X,11HFLAME SPEED   8X,11HFLAME SPEED
     3        28X,   9HDEVIATION /)
 1018 FORMAT
     9 (1H ,  10X, I8, 10X,F11.4,10X,F9.4,10X,F9.4,10X,F9.4,10X,F9.4)
 1019 FORMAT
     9 (1H0, 10X, 35HCUBIC FIT OF CURVE UNSATISFACTORY - )
 1020 FORMAT
     9 (1H+, 47X, 23HPARABOLIC FIT INDICATED )
 1021 FORMAT
     9 (1H+, 47X, 16HNO MAXIMUM FOUND  )
 1022 FORMAT
     9 (1H+, 47X, 26HMAXIMUM OUTSIDE DATA RANGE )
 1023 FORMAT
     9 (1H+, 47X, 27HMINIMUM POINT IN DATA RANGE )
 1024 FORMAT
     9 (1H0   6X, 39HPARABOLIC FIT OF CURVE UNSATISFACTORY - )
 1025 FORMAT
     9 (1H0  10X, 31HSTANDARD DEVIATION GREATER THAN  F6.3 )
 1010 FORMAT
     9 (1H0,  10X, 69HCUBIC FIT OF FLAME SPEED CURVE FAILED - MATRIX OF
     1THE COEFFICIENTS IS  /
     2  1H0,  10X  12HEQUIV. RATIO , 8X,16HEQUIV. RATIO **2 , 6X,
     3             16HEQUIV. RATIO **3 , 9X,11HFLAME SPEED  /  )
 1015 FORMAT
     9 (1H0  34X, 12HCOEFFICIENTS ,30X, 08HSTANDARD , 4X,
     1             17HEQUIVALENCE RATIO ,  6X, 7HMAXIMUM  /
     2  1H ,  15X,  2HA1 ,14X, 2HA2, 14X, 2HA3 , 14X, 2HA4 , 10X,
     3              9HDEVIATION ,  3X, 18HAT MAX FLAME SPEED , 3X,
     4             11HFLAME SPEED  / )
      END
```

SUBROUTINE TAPE

MASTER LIBRARY TAPE MODIFICATION

```
CTAPE  SUBROUTINE TAPE  FOR ROUTINE 2018  MARCH 5, 1962  MAC - DAYTON
C
C      NOMENCLATURE
C
C      A1(I) AND A2(I)  - FUEL NAME
C      ACCL(L,K)        - NUMBER OF STRUCTURAL CONTRIBUTORS PER MOLECULE
C                             IN REVISED LIST
C      AGNL(K)          - CONTRIBUTOR NAMES (FROM CARDS)
C      BI(K,I)          - NUMBER OF STRUCTURAL CONTRIBUTORS PER MOLECULE
C      BLK              - BLANK (USED IN CONTRIBUTOR NAME LIST )
C      D(K)             - DECIMAL DATA STORAGE
C      DNM(K)           - DEPENDENT VARIABLE NAME LIST
C      DU   AND TE      - FIRST AND SECOND HALVES OF DATE
C      FGCJL(J)         - NUMBER OF STRUCTURAL CONTRIBUTORS PER MOLECULE
C                          FOR CONTRIBUTOR NUMBER  LFGCCN(K)
C      FGCL(K)          - NUMBER OF STRUCTURAL CONTRIBUTORS PER MOLECULE
C                             FOR CONTRIBUTOR NUMBER  LFGCCN(K)
C      FN1  AND FN2     - FIRST AND SECOND HALVES OF FUEL NAME
C      GNL(J)           - CONTRIBUTOR NAME  (FROM TAPE)
C      I, J, K, L       - INDICIES
C      I1A(I)           - FUEL CLASS NUMBER
C      I1B(I)           - FUEL GROUP NUMBER
C      I1C(I)           - FUEL MEMBER NUMBER
C      I2(I)            - DATA SOURCE NUMBER
C      I3(I)            - EXPERIMENTAL CONDITIONS NUMBER
C      I4(I)            - NUMBER OF STRUCTURAL CONTRIBUTORS CONSIDERED
C      IADD             - NUMBER OF DATA GROUPS ACCEPTABLE FOR WRITING
C      ICANT            - OPTION CONTROL INTEGER CHECK
C      ICTL             - OPTION CONTROL INTEGER
C      IFNC             - FUEL CLASS NUMBER
C      IFNG             - FUEL GROUP NUMBER
C      IFNM             - FUEL MEMBER NUMBER
C      INDS             - DATA SOURCE CODE FOR GROUP SERIAL NUMBER ISFN
C      INEC             - DATA EXPERIMENTAL CONDITIONS CODE FOR GROUP
C                             SERIAL NUMBER ISFN
C      IPACC            - NUMBER OF CONTRIBUTOR COUNT CHANGES FOLLOWING
C                             (REMAINDER OF -G- CARD)
C      IPCN             - NUMBER OF CONTRIBUTOR NAME CHANGES FOLLOWING
C                             (SIX PER -H- CARD)
C      IPFGC            - NUMBER OF PAIRS IN CONTRIBUTOR COUNT LIST
C                             FOLLOWING ON TAPE
C      IPFM             - NUMBER OF CARDS FOLLOWING WITH CONTRIBUTOR
C                             COUNT  CHANGES  (-G- CARDS)
C      IPI              - NUMBER OF GROUPS ON TAPE 2 BEFORE ADDITIONS
C      IPIN             - NUMBER OF GROUPS ON TAPE 2 AFTER ADDITIONS
C      ISFN             - DATA GROUP SERIAL NUMBER  (FROM TAPE 2)
C      ITP              - CODE INTEGER FOR INITIAL TAPE PREPARATION
C      J1(K,I)          - SPECIES CONTRIBUTOR CODE NUMBER
C      JGNL(K)          - CONTRIBUTOR CODE NUMBER
C      K1               - NUMBER OF STRUCTURAL CONTRIBUTORS CONSIDERED
C      LACN(L,K)        - CONTRIBUTOR CODE NUMBER  (FROM CARDS)
C      LFGCCN(K)        - CONTRIBUTOR CODE NUMBER  (FROM TAPE)
C      LFMN(L)          - DATA GROUP SERIAL NUMBER  (FROM CARDS)
C      LIPACC(L)        - NUMBER OF CONTRIBUTOR COUNT CHANGES FOR DATA
C                        GROUP SERIAL NUMBER  LFMN(L)
C      M                - COUNTING INTEGER FOR LINES PRINTED PER PAGE
C      NRUN             - RUN NUMBER OF DATA GROUP
C      NRUNT            - RUN NUMBER CHECK
      SUBROUTINE  TAPE (NRUN,ICTL,A1,A2,I1A,I1B,I1C,I2,I3,DA,I4,J1,B1,
     1                  IADD, DU, TE, LAST)
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION  INT(10), DEC(10)
      DIMENSION   A1(20),A2(20),B1(100,20),DA(6,20),I1(20),I2(20),I3(20)
     1 ,I4(20),J1(100,20),ACCL(20,90),AGNL(50),D(6),DNM(6),FGCL(90),
     2 FGCJL(200),GNL(200),JGNL(50),LACN(20,90),LFMN(20),LFGCCN(90),
     3 LIPACC(20), I1A(20), I1B(20), I1C(20)
      M = 4
      WRITE OUTPUT TAPE 3, 3000,
     9              DU,TE
      WRITE OUTPUT TAPE 3, 3001,
     9              NRUN
      REWIND 6
   10 CALL INPUT
      NEX = NEX
      IF( NEX - 6) 600, 11, 33
C
C      F CARD ASSIGNMENTS
C
   11 NRUNT = J11
      ICANT = INT(1)
      IPFM =  INT(2)
      IPCN  = INT(3)
      ITP   = INT(4)
      LAST  = INT(5)
C
C      RUN NUMBER CONSISTENCY CHECK
C
      IF (NRUN - NRUNT)  29,21,29
C
C      OPTION CONTROL INTEGER CHECK
C
   21 IF (ICTL - ICANT)  29,22,29
C
C      TESTS FOR EXECUTABLE CONDITIONS
C
   22 IF (ITP + 7)  25, 28,25
   25 IF (IPFM)  26,26,32
C
C      TEST FOR GROUPS READY TO BE ADDED
C
   26 IF (IPCN)  27,27,40
   27 IF (IADD)     30,30,40
C
C      DIAGNOSTIC        - INITIAL TAPE PREPARATION
C
   28 WRITE OUTPUT TAPE 3, 3002
```

MASTER LIBRARY TAPE MODIFICATION

```
      GO TO 195
C
C       ERROR PRINT         - DATA OUT OF ORDER
C
   29 WRITE OUTPUT TAPE 3, 3003,
     9                 NRUN,NRUNT,ICTL,ICANT
      GO TO 600
C
C       DIAGNOSTIC          - NO ACTION CALLED FOR
C
   30 WRITE OUTPUT TAPE 3, 3004
      GO TO 495
   32 L = 0
  321 L = L + 1
      GO TO 10
C
C       G CARD ASSIGNMENTS
C
   33 IF( NEX - 7) 600, 330, 600
  330 NUMCON = IC - 7000
      IF( NUMCON) 332, 331, 332
  331 LFMN(L) = INT(1)
      IPACC   = INT(2)
      GO TO 10
  332 IF( NRUNT - J11) 600, 333, 600
  333 LIMIT = 10*NUMCON
      IGO   = LIMIT - 9
      IF(LIMIT - IPACC) 335, 335, 334
  334 LIMIT = IPACC
  335 M2= 0
      DO 336 K = IGO , LIMIT
      M2= M2+ 1
      LACN(L,K) = INT(M2)
  336 ACCL(L,K) = DEC(M2)
      IF( LIMIT - IPACC) 10, 35, 10
   35 LIPACC(L) = IPACC
      IF( L - IPFM ) 321, 40, 40
C
C       READING OF MASTER TAPE 6
C
   40 READ  INPUT TAPE 6, 2000
      READ  INPUT TAPE 6, 2001,  IPI
C
C       READY SCRATCH TAPE 8
C
      REWIND 8
C
C       COMPUTATIONS FOR ALTERATIONS AND ADDITIONS TO DATA GROUPS ON TAPE
C
      DO 90 I=1,IPI
C
C       READ EACH GROUP STORED ON TAPE 6
C
      READ  INPUT TAPE 6, 2002,
     9                 ISFN,FN1,FN2,IFNC,IFNG,IFNM,INDS,INEC,(D(K),K=2,6),
     1                 IPFGC,(LFGCCN(K),FGCL(K),K=1,IPFGC)
C
C       TEST FOR PROPER DATA GROUP SERIAL NUMBER SEQUENCE ON TAPE
C
      IF (I - ISFN) 41,45,41
   41 REWIND 6
      REWIND 8
C
C       TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
C     IF(M -52) 42,43,43
   43 WRITE OUTPUT TAPE 3, 3020
C
C       ERROR PRINT         - DATA GROUP SERIAL NUMBER INCONSISTENCY
C
   42 WRITE OUTPUT TAPE 3, 3005,
     9             ISFN,I
      GO TO 500
C
C       BYPASS OF TESTS IF NO CARDS TO BE READ
C
   45 IF (IPFM) 80,80,46
C
C       COMPUTATIONS FOR ADDITION OF INFORMATION TO TAPE 6
C
   46 DO 47 L=1,IPFM
C
C       TEST FOR ALTERATIONS TO GROUP ISFN ON TAPE BY DATA FROM -G- CARD
C
      IF (I - LFMN(L)) 47,50,47
   47 CONTINUE
      GO TO 80
   50 DO 51 J=1,200
C
C       ZERO COUNT LIST STORAGE
C
   51 FGCJL(J) = 0.0
      DO 52 K=1,IPFGC
C
C       STORE TAPE VALUES OF THE NUMBER OF STRUCTURAL CONTRIBUTORS PER
C              MOLECULE FOR EACH CONTRIBUTOR WITHIN THE SPECIFIED GROUP
C
      J = LFGCCN(K)
   52 FGCJL(J) = FGCL(K)
C
C       ADDITION OF NEW VALUES OF THE NUMBER OF STRUCTURAL CONTRIBUTIONS
C              PER MOLECULE FOR THOSE CONTRIBUTORS LISTED ON THE -G- CARD
C
      IPACC = LIPACC(L)
      DO 53 K=1,IPACC
      J = LACN(L,K)
```

MASTER LIBRARY TAPE MODIFICATION

```
   53 FGCJL(J) = ACCL(L,K)
      K = 0
C
C      LIST CONTRIBUTOR CODE NUMBERS AND NUMBER OF CONTRIBUTORS PER
C             MOLECULE TO BE WRITTED ON TAPE 3
C
      DO 55 J=1,200
      IF (FGCJL(J)) 54,55,54
   54 K = K + 1
      LFGCCN(K) = J
      FGCL(K) = FGCJL(J)
   55 CONTINUE
      IPFGC = K
C
C      TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
      IF(M + IPFGC/6 - 52 ) 56,57,57
   57 WRITE OUTPUT TAPE 3, 3020
      M=0
   56 M = M + IPFGC/6 +6
C
C      PRINTOUT OF ALTERED LISTS
C
      WRITE OUTPUT TAPE 3, 3006
      WRITE OUTPUT TAPE 3, 3007,
     9               ISFN,      (LFGCCN(K),FGCL(K),K=1,IPFGC)
C
C      INTERIM STORAGE ON TAPE 8
C
   80 WRITE OUTPUT TAPE 8, 2002,
     9               ISFN,FN1,FN2,IFNC,IFNG,IFNM,INDS,INEC,(D(K),K=2,6),
     1               IPFGC,(LFGCCN(K),FGCL(K),K=1,IPFGC)
   90 CONTINUE
C
C      END OF ALTERATIONS AND ADDITIONS TO DATA GROUPS ON TAPE
C
C      ALTERATIONS OR ADDITIONS TO CONTRIBUTOR NAME LIST
C
C
C      READ CONTRIBUTOR NAMES AND DEPENDENT VARIABLE NAME LIST FROM TAPE
      READ  INPUT TAPE 6, 2003,
     9               (GNL(J),J=1,200)
      READ  INPUT TAPE 6, 2003,
     9               (DNM(K),K=1,6)
      REWIND 6
      REWIND 8
C
C      TEST FOR ALTERATION OR ADDITION
C
      IF (IPCN) 100,100,95
C
C      H  CARD READING
C
   95 READ INPUT TAPE 2, 1001,
     9               (JGNL(K),AGNL(K),K=1,IPCN)
C
C      TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
      IF(M + IPCN/7 - 52) 97,98,98
   98 WRITE OUTPUT TAPE 3, 3020
      M=0
   97 M=M + IPCN/7 +6
C
C      PRINTOUT OF ALTERATIONS OR ADDITIONS TO CONTRIBUTOR NAME LIST
C
      WRITE OUTPUT TAPE 3, 3008
      WRITE OUTPUT TAPE 3, 3009,
     9                    (JGNL(K),AGNL(K),K=1,IPCN)
      DO 96 K=1,IPCN
      J = JGNL(K)
C
C      ADD ALTERED OR NEW NAMES TO LIST
C
   96 GNL(J) = AGNL(K)
C
C      REVISE GROUP COUNT
C
  100 IPIN = IPI + IADD
C
C      PREPARE CORRECTED TAPE 6
C
      WRITE OUTPUT TAPE 6, 2000
      WRITE OUTPUT TAPE 6, 2001,
     9               IPIN
C      (A)        - CORRECTED GROUPS PREVIOUSLY ON TAPE
C
      DO 110 I = 1,IPI
      READ  INPUT TAPE 8, 2002,
     9               ISFN,FN1,FN2,IFNC,IFNG,IFNM,INDS,INEC,(D(K),K=2,6),
     1               IPFGC,(LFGCCN(K),FGCL(K),K=1,IPFGC)
  110 WRITE OUTPUT TAPE 6, 2002,
     9               ISFN,FN1,FN2,IFNC,IFNG,IFNM,INDS,INEC,(D(K),K=2,6),
     1               IPFGC,(LFGCCN(K),FGCL(K),K=1,IPFGC)
      IF (IADD) 115,115,117
C
C      TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
  115 IF(M - 56) 113,114,114
  114 WRITE OUTPUT TAPE 3, 3020
      M=0
  113 M=M+2
C
C      DIAGNOSTIC        - NO NEW DATA GROUPS ADDED TO TAPE
C
      WRITE OUTPUT TAPE 3, 3011
      GO TO 140
```

MASTER LIBRARY TAPE MODIFICATION

```
C
C     (B)        - ADDITION OF NEW GROUPS TO TAPE
C
C
C     TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
  117 IF(M - 52) 118,116,116
  116 WRITE OUTPUT TAPE 3, 3020
      M=0
  118 M=M+5
C
C     PRINTOUT OF NEW GROUPS ADDED TO TAPE
C
      WRITE OUTPUT TAPE 3, 3012
  120 DO 130 I=1,IADD
      ISFN = IPI + I
      K1 = I4(I)
      IF(M - 58) 129,128,128
  128 WRITE OUTPUT TAPE 3, 3020
      WRITE OUTPUT TAPE 3, 3012
      M=0
  129 M=M+1
      WRITE OUTPUT TAPE 3, 3013,
     9           A1(I),A2(I), ISFN ,I1A(I),I1B(I),I1C(I),I2(I),I3(I),
     1             DA(2,I), DA(4,I), DA(3,I), DA(5,I), DA(6,I)
  130 WRITE OUTPUT TAPE 6, 2002,
     9             ISFN,A1(I),A2(I),I1A(I),I1B(I),I1C(I),I2(I),I3(I),
     1             (DA(K,I),K=2,6),K1,(J1(K,I),B1(K,I),K=1,K1)
C
C     TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
      IF(M+I4(I)/6 - 50) 131,132,132
  132 WRITE OUTPUT TAPE 3, 3020
      M=0
  131 M=M+6
      WRITE OUTPUT TAPE 3, 3014
      DO 135 I=1,IADD
      ISFN = IPI + I
      K1 = I4(I)
C
C     TEST TO LIMIT THE NUMBER OF LINES PRINTED PER PAGE OF OUTPUT
C
      IF(M+I4(I)/6 - 56) 133,134,134
  134 WRITE OUTPUT TAPE 3, 3020
      WRITE OUTPUT TAPE 3, 3014
      M=6
  133 M=M+I4(I)/6 +2
  135 WRITE OUTPUT TAPE 3, 3007,
     9             ISFN,      (J1(K,I),B1(K,I),K=1,K1)
C
C     (C)        - ADDITION OF CONTRIBUTOR NAME LIST TO TAPE
C
  140 WRITE OUTPUT TAPE 6, 2003,
     9             (GNL(J),J=1,200)
      WRITE OUTPUT TAPE 6, 2003,
     9             (DNM(K),K=1,6)
      END FILE 6
      REWIND 6
      REWIND 8
      GO TO 500
C
C     END OF OPERATIONS ON ALTERATIONS AND ADDITIONS TO TAPE 2
C
C     OPERATIONS FOR INITIAL MAKEUP OF TAPE 2
C
  195 IF (IPCN) 490,490,210
C
C     TITLE CARD READING
C
  210 READ INPUT TAPE 2, 2000
C
C     H  CARD READING
C
      READ INPUT TAPE 2, 1001,
     9             (JGNL(K),AGNL(K),K=1,IPCN)
C
C     DEPENDENT VARIABLE NAME LIST CARD READING
C
      READ INPUT TAPE 2, 1002,
     9             (DNM(K),K=1,6),BLK
      DO 215  J=1,200
C
C     BLANK OUT ENTIRE CONTRIBUTOR NAME FIELD
C
  215 GNL(J) = BLK
      DO 220  K=1,IPCN
      J = JGNL(K)
C
C     STORE GROUPS FROM -H- CARD IN CONTRIBUTOR NAME FIELD
C
  220 GNL(J) = AGNL(K)
      IF (IADD) 490,490,230
C
C     PRINTOUT OF INITIAL DATA FOR TAPE
C
  230 WRITE OUTPUT TAPE 3, 2000
      WRITE OUTPUT TAPE 3, 3010
      WRITE OUTPUT TAPE 3, 3009,
     9                   (JGNL(K),AGNL(K),K=1;IPCN)
      WRITE OUTPUT TAPE 3, 3015,
     9             (DNM(K),K=1,6),BLK
C
C     PREPARE TAPE 6
C
      WRITE OUTPUT TAPE 6, 2000
      WRITE OUTPUT TAPE 6, 2001,
```

MASTER LIBRARY TAPE MODIFICATION

```
     9                IADD
      DO 240 I=1,IADD
      K1 = I4(I)
  240 WRITE OUTPUT TAPE 6, 2002,
     9                I    ,A1(I),A2(I),I1A(I),I1B(I),I1C(I),I2(I),I3(I),
     1                (DA(K,I),K=2,6),K1,(J1(K,I),B1(K,I),K=1,K1)
      WRITE OUTPUT TAPE 6, 2003,
     9                 (GNL(J),J=1,200)
      WRITE OUTPUT TAPE 6, 2003,
     9                 (DNM(K),K=1,6)
      END FILE 6
      WRITE OUTPUT TAPE 3, 3016
      REWIND 6
C
C      END OF INITIAL PREPARATION OF TAPE 6
C
      GO TO 500
C
C      ERROR PRINT       - NO DATA FOR INITIAL TAPE PREPARATION
C
  490 WRITE OUTPUT TAPE 3, 3017,
     9              IPCN,IADD
  495 REWIND 6
  500 RETURN
  600 NEX = 2
      WRITE OUTPUT TAPE 3, 4000, IC, J11
      GO TO 500
C
C      FORMAT STATEMENTS
C
 1001 FORMAT
     9 (12X          ,I4,2X,A6,I4,2X,A6,I4,2X,A6,I4,2X,A6,I4,2X,A6)
 1002 FORMAT ( 12X, 7A6 )
 2000 FORMAT(1H1,11X60H
     1          )
 2001 FORMAT
     9    (1HO 6I6)
 2002 FORMAT
     9 (1HO I6,2A6,5I6,1P5E12.4,I6/(1H I6,E12.4,I6,E12.4,I6,E12.4,I6,
     1E12.4,I6,E12.4,I6,E12.4))
 2003 FORMAT
     9    (1HO 9(6X,A6)/(1H 6X,A6,6X,A6,6X,A6,6X,A6,6X,A6,6X,A6,6X,A6,6X,
     1A6,6X,A6))
 3000 FORMAT
     9 (1H1, 3X, 102HMONSANTO RESEARCH CORPORATION FLAME SPEED CALCULATI
     1ON    -    ROUTINE 2018     MODIFICATION 1     DATE     2A6 )
 3001 FORMAT
     9 (1HO,10X,  38HTAPE 2 WRITING INFORMATION    -    RUN  I4  )
 3002 FORMAT
     9 (1HO,15X,  28H     INITIAL TAPE PREPARATION   )
 3003 FORMAT
     9 ( 1HO, 16X,30HDATA OUT OF ORDER - RUN NUMBER    I4,
     1         14X,          20HMISPLACED RUN NUMBER   I4,
     2  /1HO  16X,22HOPTION CONTROL INTEGER      I4,
     3        22X,21HCONTROL INTEGER CHECK       I4)
 3004 FORMAT
     9 (1HO,10X,  20HNO ACTION CALLED FOR  )
 3005 FORMAT
     9 (1HO,10X,  57HGROUP SERIAL NUMBER INCONSISTENCY    -    SERIAL NUMB
     1ER  = I4 , 5X, 11HLOCATION = I4 )
 3006 FORMAT
     9 (1HO,10X, 34HALTERATIONS TO DATA GROUPS ON TAPE  /
     1  1H ,14H  DATA GROUP   ,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11H
     2CONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR
     3/ 1H ,117H   SERIAL           CODE   COUNT /   CODE   COUNT /   CODE
     4   COUNT /   CODE   COUNT /   CODE   COUNT /   CODE   COUNT /
     5/ 1H ,118H   NUMBER           NUMBER  MOLECULE NUMBER  MOLECULE NUMBE
     6R  MOLECULE NUMBER  MOLECULE NUMBER  MOLECULE NUMBER  MOLECULE  /)
 3007 FORMAT
     9 (1HO, I10,7X, 6(I6,2X,F7.3,2X) /(1H ,17X,I6,2X,F7.3,2X,I6,2X,F7.3
     1,2X,I6,2X,F7.3,2X,I6,2X,F7.3,2X,I6,2X,F7.3,2X,I6,2X,F7.3 ))
 3008 FORMAT
     9 (1HO,10X, 32HCHANGES IN CONTRIBUTOR NAME LIST )
 3009 FORMAT
     9 (1HO,14H   CONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11H
     1CONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR
     2/ 1H ,  5H CODE 13X,4HCODE 13X,4HCODE 13X,4HCODE 13X,4HCODE 13X,
     3          4HCODE 13X,4HCODE   /
     4  1H ,117HNUMBER     NAME    NUMBER     NAME    NUMBER     NAME    NUMBE
     5R     NAME    NUMBER     NAME    NUMBER     NAME    NUMBER     NAME   /
     6/(1H , I6,2X,A6,3X,I6,2X,A6,3X,I6,2X,A6,3X,I6,2X,A6,3X,I6,2X,A6,3X
     7,I6,2X,A6,3X,I6,2X,A6 ) )
 3010 FORMAT
     9 (1HO,10X, 29HINITIAL CONTRIBUTOR NAME LIST  )
 3011 FORMAT
     9 (1HO,10X,  32HNO NEW DATA GROUPS ADDED TO TAPE )
 3012 FORMAT
     9 (1HO,10X,  25HDATA GROUPS ADDED TO TAPE  /
     1  1H , 10H FUEL NAME 19X,12HCODE NUMBERS 22X,14HSTOICHIOMETRIC 11X
     2,13HMAXIMUM SPEED  6X,11HEQUIVALENCE   /1H ,13X,103HSERIAL CLASS G
     3ROUP MEMBER  DATA  EXPERIMENT   FLAME          FUEL          FLAME
     4     FUEL          RATIO AT   /
     5  1H ,39X,77HSOURCE CONDITIONS    SPEED    CONCENTRATION    SPEED
     6 CONCENTRATION   MAXIMUM /1H ,57X,61H(CM./SEC) (MOLECULES/CC) (CM.
     7/SEC) (MOLECULES/CC) FLAME SPEED  /)
 3013 FORMAT
     9 (1H , 2A6, I7,2I6, 3I7, 4X, F9.4, 2X,1PE12.4,2X, 0PF9.4,2X,1PE12.
     24,3X, 0PF8.4 )
 3014 FORMAT
     9 (1HO,10X, 32HADDITIONS TO DATA GROUPS ON TAPE   /
     1  1H ,14H  DATA GROUP   ,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11H
     2CONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR,6X,11HCONTRIBUTOR
     3/ 1H ,117H   SERIAL           CODE   COUNT /   CODE   COUNT /   CODE
     4   COUNT /   CODE   COUNT /   CODE   COUNT /   CODE   COUNT /
     5/ 1H ,118H   NUMBER           NUMBER  MOLECULE NUMBER  MOLECULE NUMBE
     6R  MOLECULE NUMBER  MOLECULE NUMBER  MOLECULE NUMBER  MOLECULE  /)
```

SUBROUTINE CROUT

MATRIX INVERSION FOR SUBROUTINE MAXM

```
CCRT    CROUT SUBROUTINE MOD 100 PROBLEM 2018  MARCH 1, 1962  NRC DAYTON
C
C       NOMENCLATURE
C
C       DIVISR            - NON-ZERO DIAGONAL ELEMENT DIVISOR
C       ID, JN, K, I, J,
C           J1            - INDICIES
C       ITCTR             - ITERATION COUNTER
C       NVAR              - NUMBER OF INDEPENDENT VARIABLES IN EQUATIONS
C       W, W(I),   Y(I)   - COEFFICIENTS (OUTPUT)
C       Z, Z(I,J), X(I,J)- MATRIX OF INDEPENDENT VARIABLES (INPUT)
C
      SUBROUTINE CROUT(NVAR,Z,W)
      DIMENSION X(10,11),Y(10),Z(10,11),W(10)
      JN=NVAR+1
    1 DO 2 I=1,NVAR
      DO 2 J=1,JN
    2 X(I,J)=Z(I,J)
      ITCTR=0
    3 ID= 1
C
C       TEST FOR TWO OR MORE VARIABLES
C
      IF(NVAR-1)100,100,8
C
C       TEST OF ZERO DIAGONAL ELEMENT
C
    8 IF(X(ID,ID)) 9,11,9
    9 DIVSR= X(ID,ID)
      DO 10 J=ID,JN
   10 X(ID,J)= X(ID,J)/DIVSR
      I1=ID+1
C
C       INVERSION OF MATRIX
C
      DO 20 I=I1,NVAR
      DO 20 J=I1,JN
   20 X(I,J)= X(I,J) -((X(ID,J))* (X(I,ID)))
      IF (ID-JN+2)21,22,23
C
C       SIGNAL FLAG TO INDICATE SOLUTION NOT POSSIBLE
C
   23 SENSE LIGHT 4
      GOTO 50
   21 ID=ID+1
      GO TO 8
   22 ID= ID +1
C
C       TEST FOR ZERO DIAGONAL ELEMENT
C
      IF(X(ID,ID)) 24,11,24
C
C       SIGNAL FLAG TO INDICATE SOLUTION NOT POSSIBLE
C
   11 SENSE LIGHT 3
      GO TO 50
   24 DIVSR = X(ID,ID)
C
C       INVERSION OF MATRIX
C
      DO 25 J= ID,JN
   25 X(ID,J) =X(ID,J)/DIVSR
      K=NVAR
      Y(K)= X(NVAR,JN)
  126 IF(K-1)150,150,26
   26 K =K-1
      Y(K) = X(K,JN)
      J1= K+1
      DO 30 J=J1,NVAR
   30 Y(K) = Y(K)- (X(K,J))*(Y(J))
      GO TO 126
   50 RETURN
  100 W(1)= X(1,2)/X(1,1)
      IF DIVIDE CHECK 11, 50
  150 IF (ITCTR) 151,151,200
C
C       COEFFICIENT STORAGE IN OUTPUT VECTOR
C
  151 DO 352 I =1,NVAR
  352 W (I) = Y(I)
      GO TO 251
  200 DO 201 I =1,NVAR
  201 W(I)= W(I) - Y(I)
C
C       TEST FOR SATISFACTORY COMPLETION OF SOLUTION
C
      IF(ITCTR-3)251,50,50
  251 ITCTR = ITCTR +1
      DO 152 I = 1,NVAR
      DO 152 J = 1,NVAR
  152 X(I,J) = Z(I,J)
      DO 153 I =1,NVAR
      X (I,JN) = -1.0 * Z (I,JN)
      DO 153 J = 1,NVAR
  153 X(I,JN) = X(I,JN)+ (X(I,J))* (W(J))
      GO TO 3
      END
```

SUBROUTINE FSC1

DATA CARD INPUT

```
CFSC1  DATA CARD INPUT SUBROUTINE FOR FLAME SPEED CALCULATIONS
      SUBROUTINE INPUT
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION INT(10), DEC(10),  KARRAY(10), PARRAY(10)
      NIN = NIN
    4 NUMDCP =3
      KPASS  =0
  401 KPASS  =KPASS+1
      CALL VOECOM(NUMDCP, KARRAY, PARRAY,KPASS)
      GO TO(402, 405, 410), KPASS
  402 I = KARRAY(1)
      IC = I
      L = I/1000
      IF( IC) 4020, 4, 4020
 4020 J11 = KARRAY(2)
      J2= KARRAY(3)
      NUMDCP = J2 + 1
      GO TO 401
  405 DO 406  J=1,J2
  406 INT(J) = KARRAY(J)
      J3  =KARRAY(J2+1)
      NUMDCP = J3
      GO TO 401
  410 DO 412  J=1, J3
  412 DEC(J) = PARRAY(J)
      NEX = L
      GO TO ( 50, 60), NIN
   49 NIN = 1
   50 RETURN
   60 IF( IC - 1000) 4, 49, 4
      END
```

SUBROUTINE VDECOM

INTEGER INPUT DATA DECOMPOSITION

```
      SUBROUTINE VDECOM(N ,    KARRAY,P     ,KPASS)
      DIMENSION P(10)
      DIMENSION IDUMMY(30), DUMMY(30)
      DIMENSION KINPUT(72), KARRAY(10), PARRAY(10),AINPUT(72),
     1           KOUTPT(72), AOUTPT(72)
      COMMON IDUMMY, IPLUS, IMINUS, IDECPT, ICOMMA, IE, IBLANK,
     1  KINPUT, NUMDCP, PARRAY, I, L, NEX, N1
      EQUIVALENCE ( DUMMY, IDUMMY )
     9           ,(PLUS,IPLUS),(AMINUS,IMINUS), (DECPT,IDECPT),
     1            (COMMA,ICOMMA),(E, IE),( BLANK, IBLANK),
     2            (AINPUT, KINPUT), (AOUTPT, KOUTPT)
      REWIND 5
      NUMDCP = N
      NEX =1
      N1 = 1
      L = 1
      GO TO( 1,10, 50), KPASS
    1 CONTINUE
C      SET UP CHARACTERS FOR LATER TEST
B     PLUS   = 206060606060
B     AMINUS = 406060606060
B     DECPT  = 336060606060
B     COMMA  = 736060606060
B      E     = 256060606060
B     BLANK  = 606060606060
C      READ ALPHANUMERIC CHARACTERS
    5 READ INPUT TAPE 2,1000, (AINPUT(J),J=1,72)
      I=1
      GO TO(10, 10, 50), KPASS
C      DECOMPOSITION OF INTEGERS
   10 DO 21 N = N1, NUMDCP
      N1 = N
C      SEARCH FOR START OF NUMBER
  101 IF (KINPUT(I) - IBLANK) 102, 11, 102
  102 IF (KINPUT(I) - ICOMMA) 12 , 11,  12
   11 I= I+1
      IF( I -72)101,101, 5
C      SELECT INTEGERS
   12 L1 = L
      M = 0
      DO 20 J=1,6
      KOUTPT(L) = KINPUT(I)
      IF( KINPUT(I) - IMINUS) 122, 120, 122
  122 IF( KINPUT(I) - IPLUS) 123, 120, 123
  120 M = 1
  123 L = L + 1
      I= I+1
      IF(KINPUT(I) -IBLANK)121 ,13 ,121
  121 IF(KINPUT(I) -ICOMMA) 20 ,13 , 20
C      RIGHT ADJUST IN FIELD
   13 IF( J-6) 14,21,14
   14 KDO = J - M
      DO 15 K = 1, KDO
      L2 = L1 + 6 - K
      L3 = L1 + J  - K
   15 KOUTPT(   L2 )= KOUTPT(  L3 )
      L = L1 + 6
      KDO = 6-J  + M
      KGO = 1 + M
      DO 16 K = KGO, KDO
      L4 = L1 + K   -1
   16 KOUTPT(  L4)  = 0
      GO TO 21
   20 CONTINUE
   21 CONTINUE
      IEND = 6* NUMDCP
C      WRITE ALPHANUMERIC CHARACTERS
      WRITE OUTPUT TAPE 5,1000, (AOUTPT(J), J=1, IEND)
      REWIND 5
C      READ INTEGER LIST
      READ INPUT TAPE 5,1001,  (KARRAY(J), J=1,NUMDCP)
      REWIND 5
   60 RETURN
   50 CALL DECDCP
      NEX = NEX
      GO TO(30,5), NEX
   30 DO 31 J = 1, NUMDCP
   31 P(J) = PARRAY(J)
      GO TO 60
 1000 FORMAT(72A1)
 1001 FORMAT(11I6)
      END
```

SUBROUTINE DECDCP

FLOATING POINT INPUT DATA DECOMPOSITION

```
      SUBROUTINE DECDCP
      COMMON IDUMMY, IPLUS, IMINUS, IDECPT, ICOMMA, IE, IBLANK,
     1 KINPUT, NUMDCP, PARRAY, I, L, NEX, N1
      EQUIVALENCE ( DUMMY, IDUMMY )
      EQUIVALENCE (AOUTPT, KOUTPT)
      DIMENSION  AOUTPT(72), KOUTPT(72), PARRAY(10) , KINPUT(72)
      DIMENSION IDUMMY(30), DUMMY(30)
      NEX = NEX
      M = L
      GO TO (50,51),NEX
C      DECOMPOSITION OF DECIMAL AND EXPONENTIAL NUMBERS
C      LIMIT DECOMPOSITION TO 6 NUMBERS
   50 IF(NUMDCP -6)503,503,502
  502 IDEC = 6
      IEND = 12*IDEC
      GO TO 504
  503 IDEC = NUMDCP
      IEND = 12* NUMDCP
  504 IF(I -72) 51,51,505
  505  NEX = 2
       GO TO 300
   51 NEX = 1
      DO 100  N= N1, IDEC
      N1 = N
C      SEARCH FOR START OF NUMBER
  510 IF(KINPUT(I)- IBLANK) 52, 53, 52
   52 IF(KINPUT(I)- ICOMMA) 54, 53, 54
   53 I= I + 1
      IF( I - 72) 510, 510, 505
   54 M1 = M
C      STORE NUMBERS UP TO DECIMAL POINT
  541 IF(KINPUT(I) - IDECPT) 55, 65, 55
   55 KOUTPT(M) = KINPUT(I)
      I= I +1
      M= M +1
      GO TO 541
C      TEST FOR END OF NUMBER OR EXPONENTIAL
   60 IF(KINPUT(I) - IE      ) 61, 70,61
   61 IF(KINPUT(I) - IPLUS   ) 62, 70,62
   62 IF(KINPUT(I) - IMINUS  ) 63, 70,63
   63 IF(KINPUT(I) - ICOMMA  ) 64, 80,64
   64 IF(KINPUT(I) - IBLANK  ) 65, 80,65
C      STORE DECIMAL POINT AND NUMBERS
   65 KOUTPT(M) = KINPUT(I)
      I= I+1
      M= M+1
      GO TO 60
C      COMPLETE EXPONENTIAL FIELD THROUGH 8 LOCATIONS
   70 LDO = M1 + 7
      DO 71 J1= M, LDO
   71 KOUTPT(J1) = 0
      M = M1 + 8
C      STORE E IN LOCATION 9
      KOUTPT(M) = IE
      IF(KINPUT(I)- IE) 73,72,73
   72 I= I+1
C      TEST FOR SIGN OF EXPONENT
   73 IF(KINPUT(I)-IMINUS) 74, 76,74
   74 IF(KINPUT(I)-IPLUS ) 75, 76 ,75
   75 KOUTPT(M+1) = IPLUS
      GO TO 77
C      STORE SIGN
   76 KOUTPT(M+1) = KINPUT(I)
      I=I+1
C      TEST FOR END OF EXPONENT
   77 IF(KINPUT(I+1) - IBLANK) 78, 79, 78
   78 IF(KINPUT(I+1) - ICOMMA) 791,79 ,791
   79 KOUTPT(M+2) = 0
      KOUTPT(M+3) = KINPUT(I)
      GO TO 792
  791 KOUTPT(M+2) = KINPUT(I)
      KOUTPT(M+3) = KINPUT(I+1)
  792 I= I+2
      M = M1 + 12
      GO TO 100
C      COMPLETE DECIMAL FIELD
   80 LDO = M1 + 11
      DO 81 J1 = M , LDO
   81 KOUTPT(J1) = 0
      M = M1 + 12
  100 CONTINUE
C      WRITE ALPHANUMERIC CHARACTERS
      WRITE OUTPUT TAPE 5,1000,(AOUTPT(J),J=1, IEND)
      IF(NUMDCP - IDEC ) 201, 201, 200
  200 M = 1
      N1 = N1 + 1
      IEND = 12*(NUMDCP - 6)
      IDEC = NUMDCP
      GO TO 504
  201 REWIND 5
C      READ DECIMAL AND EXPONENTIAL LIST
      READ INPUT TAPE  5,1010,(PARRAY(J),J=1, NUMDCP)
      REWIND 5
  300 L = M
      RETURN
 1000 FORMAT(72A1)
 1010 FORMAT(6F12.5)
      END
```

MONSANTO RESEARCH CORPORATION FLAME SPEED CALCULATION - ROUTINE 2018 MODIFICATION 1 RUN 735 DATE 5/9/61

INPUT DATA

FUEL NAME	INHIBITORS USED
HYDROGEN	

FUEL CLASS NUMBER 0 FUEL GROUP NUMBER 0 FUEL MEMBER NUMBER 0

DATA SOURCE NUMBER 1 EXPERIMENTAL CONDITIONS NUMBER 1

FLAME VELOCITY AT STOICHIOMETRIC CONCENTRATION RATIO 0. CM./SEC.

MAXIMUM FLAME VELOCITY 0. CM./SEC.

FUEL CONCENTRATION AT STOICHIOMETRIC CONDITIONS 0. MOLECULES/CC.

FUEL CONCENTRATION AT CONDITIONS OF MAXIMUM VELOCITY 0. MOLECULES/CC.

EQUIVALENCE RATIO AT MAXIMUM FLAME SPEED 0.

SPECIES CONTRIBUTOR CODE NUMBER	NUMBER OF CONTRIBUTORS PER MOLECULE OF FUEL
1	2.000
2	2.000
2	3.000
3	2.000
4	4.000
5	5.000
6	6.000
7	7.000

EXPERIMENTAL DATA

MIXTURE TEMPERATURE 25.0 DEG. C. MIXTURE PRESSURE 760.0 MM. MERCURY

ATOMS OF OXYGEN TO COMPLETELY OXIDIZE ONE MOLECULE OF FUEL 1.00

MOLE FRACTION OXYGEN IN OXIDANT 0.2100

VOLUME PER MOLE OF FUEL 2.2414E 04 CC. PER GRAM-MOLE

FLAME FRONT DIMENSIONS

RUN

735 PEAK HEIGHT (MEASURED UNITS) 63.00

STATION (MEASURED)	1	2	3	4	5	
DIAMETER (MEASURED)	41.000	30.000	21.000	14.000	6.500	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	0.94555
DIAMETER (CM.)	0.61538	0.45028	0.31520	0.21013	0.09756	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 266.50000 UNITS

736 PEAK HEIGHT (MEASURED UNITS) 62.00

STATION (MEASURED)	1	2	3	4	5	
DIAMETER (MEASURED)	40.500	30.000	21.000	13.500	6.500	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	0.93058
DIAMETER (CM.)	0.60788	0.45028	0.31520	0.20263	0.09756	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 266.50000 UNITS

737 PEAK HEIGHT (MEASURED UNITS) 65.00

STATION (MEASURED)	1	2	3	4	5	
DIAMETER (MEASURED)	42.000	31.000	22.000	15.000	8.000	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	0.98299
DIAMETER (CM.)	0.63516	0.46881	0.33270	0.22684	0.12098	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 264.50000 UNITS

738 PEAK HEIGHT (MEASURED UNITS) 73.00

STATION (MEASURED)	1	2	3	4	5	6	
DIAMETER (MEASURED)	42.000	32.500	24.000	18.000	11.500	5.500	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	1.00000	1.09981
DIAMETER (CM.)	0.63277	0.48564	0.36158	0.27119	0.17326	0.08286	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 265.50000 UNITS

739 PEAK HEIGHT (MEASURED UNITS) 73.00

STATION (MEASURED)	1	2	3	4	5	6	
DIAMETER (MEASURED)	41.500	32.500	25.000	18.500	11.500	5.500	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	1.00000	1.09981
DIAMETER (CM.)	0.62524	0.48564	0.37665	0.27872	0.17326	0.08286	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 265.50000 UNITS

740 PEAK HEIGHT (MEASURED UNITS) 75.00

STATION (MEASURED)	1	2	3	4	5	6	
DIAMETER (MEASURED)	42.500	34.000	26.000	19.000	12.500	7.000	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	1.00000	1.11732
DIAMETER (CM.)	0.63315	0.50652	0.38734	0.28305	0.18622	0.10428	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 268.50000 UNITS

741 PEAK HEIGHT (MEASURED UNITS) 77.00

STATION (MEASURED)	1	2	3	4	5	6	
DIAMETER (MEASURED)	43.000	36.000	27.000	21.000	15.000	8.500	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	1.00000	1.15140
DIAMETER (CM.)	0.64259	0.53832	0.40374	0.31402	0.22430	0.12710	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 267.50000 UNITS

742 PEAK HEIGHT (MEASURED UNITS) 88.00

STATION (MEASURED)	1	2	3	4	5	6	7	
DIAMETER (MEASURED)	44.000	37.000	30.500	24.000	17.500	13.000	7.000	
HEIGHT (CM.)	0.	0.20000	0.40000	0.60000	0.80000	1.00000	1.20000	1.31099
DIAMETER (CM.)	0.65549	0.55121	0.45438	0.35754	0.26071	0.19367	0.10428	0.

ACTUAL LENGTH OF REFERENCE 4.00000 CM. MEASURED LENGTH OF REFERENCE 268.50000 UNITS

RUN	FUEL FLOW (CC./SEC)	OXIDANT FLOW (CC./SEC)	MOLE FRACTION INHIBITOR	VOLUME FLOW (CC./SEC)	CONE AREA (SQ. CM.)	FLAME SPEED (CM./SEC)	EQUIVALENCE RATIO
735	75.20000	137.30000	0.	231.95763	0.91060	254.73146	1.30406
736	51.40000	137.30000	0.	249.64099	0.89899	277.68917	1.58499
737	107.60000	137.30000	0.	267.32434	0.97310	274.71471	1.86592
738	124.00000	137.30000	0.	285.22602	1.09941	259.43550	2.15031
739	124.00000	126.80000	0.	273.76458	1.10800	247.07953	2.32038
740	124.00000	116.50000	0.	262.52146	1.15208	227.86642	2.53423
741	124.00000	106.20000	0.	251.27834	1.24648	201.55869	2.78002
742	124.00000	86.00000	0.	229.22872	1.43982	159.20607	3.43300

FLAME SPEED CURVE DATA

COEFFICIENTS A1	A2	A3	A4	STANDARD DEVIATION	EQUIVALENCE RATIO AT MAX FLAME SPEED	MAXIMUM FLAME SPEED
-2.4707E 02	7.5649E 02	-3.2718E 02	4.1656E 01	1.5729	1.72288	278.0486

RUN	EQUIVALENCE RATIO	MEASURED FLAME SPEED	PREDICTED FLAME SPEED	DEVIATION	PERCENT DEVIATION
735	1.3041	254.7315	255.3638	-0.6324	-0.2476
736	1.5850	277.4892	275.8121	1.6771	0.6081
737	1.8459	274.7147	275.8816	-1.1669	-0.4230
738	2.1503	259.4355	260.8619	-1.4264	-0.5468
739	2.3284	247.0795	246.2792	0.8003	0.3250
740	2.5162	227.8664	226.6501	1.2163	0.5366
741	2.7800	201.5587	202.2344	-0.6757	-0.3341
742	3.6330	159.2061	159.1984	0.0077	0.0048

DATA ACCEPTABLE

FUEL NAME	INHIBITORS USED
HYDROGEN	

FUEL CLASS NUMBER	0	FUEL GROUP NUMBER	0	FUEL MEMBER NUMBER	0
DATA SOURCE NUMBER	1	EXPERIMENTAL CONDITIONS NUMBER	1		

FLAME VELOCITY AT STOICHIOMETRIC CONCENTRATION RATIO	203.8507	CM./SEC
MAXIMUM FLAME VELOCITY	278.0486	CM./SEC
FUEL CONCENTRATION AT STOICHIOMETRIC CONDITIONS	0.728220E 19	MOLECULES/CC.
FUEL CONCENTRATION AT CONDITIONS OF MAXIMUM VELOCITY	0.103363E 20	MOLECULES/CC.
EQUIVALENCE RATIO AT MAXIMUM FLAME SPEED	1.72208	

APPENDIX B

Fortrar rogram and Sample Printouts
for Routine FSR

ROUTINE FSR

FLAME SPEED REGRESSION CALCULATIONS

```
*62-215      10000    7  O.S. MRC7617 RINGROSE
*       LIST8
*       SYMBOL TABLE
CFSR    FLAME SPEED REGRESSION ROUTINE 1922A  MRC - DAYTON MARCH 12, 1962
C
C       NOMENCLATURE
C
C       CGC(K,KDV)          - INPUT LIST OF PRESPECIFIED CONTRIBUTOR
C                                   COEFFICIENTS
C       CGCJ(J)             - LIST OF PRESPECIFIED COEFFICIENTS
C       D(K)                - FLAME SPEED DATA
C       DNM(K)              - NAME LIST OF DEPENDENT VARIABLE COMPONENTS
C       FGCJ(J)             - INTERNAL FULL LIST OF CONTRIBUTOR COUNTS
C       FGCL(K)             - INPUT TAPE LIST OF CONTRIBUTOR COUNTS
C       FN1 AND FN2         - FIRST AND SECOND HALVES OF FUEL NAME (ON TAPE)
C       FN1L(N) AND
C       FN2L(N)             - FIRST AND SECOND HALVES OF ACCEPTED FUEL
C                                   NAMES LIST
C       GNL(J)              - INPUT TAPE LIST OF CONTRIBUTOR NAMES
C       I                   - DATA SERIAL NUMBER INDEX
C       ICFN                - FUEL CLASS NUMBER (ON TAPE)
C       IGFN                - FUEL GROUP NUMBER (ON TAPE)
C       IMFN                - FUEL MEMBER NUMBER (ON TAPE)
C       INDS                - DATA SOURCE NUMBER (ON TAPE)
C       INEC                - EXPERIMENTAL CONDITIONS NUMBER (ON TAPE)
C       IPCFN               - NUMBER OF ENTRIES IN INPUT LIST OF ACCEPTABLE
C                                 FUEL CLASS NUMBERS
C       IPCTC               - NUMBER OF ENTRIES IN INPUT LIST OF CONDITIONAL
C                                 TEST  CRITERIA
C       IPCTC3              - NUMBER OF CONDITIONAL TESTS + 3
C       IPDV                - NUMBER OF DEPENDENT VARIABLES TO BE REGRESSED
C       IPCGC               - NUMBER OF ENTRIES IN (KDV)TH LIST OF
C                                   PRESPECIFIED COEFFICIENTS
C       IPGFN               - NUMBER OF ENTRIES IN INPUT LIST OF ACCEPTABLE
C                                 FUEL CLASS-GROUP NUMBERS
C       IP1                 - NUMBER OF DATA GROUPS ON TAPE 2
C       IPIGTN              - NUMBER OF DUAL ENTRIES IN INPUT LIST OF
C                                 CONTRIBUTOR TESTS
C       IPJ                 - HIGHEST VALUE OF CONTRIBUTOR NUMBER INDEX
C       IPLRC               - NUMBER OF DUAL ENTRIES IN INPUT LIST OF
C                                 INTEGERS TO OVERRIDE REGRESSION CONTROL
C                                 DATA
C       IPM                 - NUMBER OF INDEPENDENT VARIABLES FOR REGRESSION
C       IPMC                - NUMBER OF PRESPECIFIED COEFFICIENTS IN
C                                   REGRESSION DATA
C       IPMFN               - NUMBER OF ENTRIES IN INPUT LIST OF
C                                 UNACCEPTABLE FUEL MEMBER NUMBERS
C       IPN                 - NUMBER OF ACCEPTED DATA GROUPS FOR REGRESSION
C       IPRCL               - NUMBER OF ENTRIES IN INPUT LIST OF DECIMAL
C                                 DATA TO OVERRIDE REGRESSION CONTROL DATA
C       IPSFN               - NUMBER OF ENTRIES IN INPUT LIST OF ACCEPTABLE
C                                 DATA SERIAL NUMBERS
C       ISFN                - DATA GROUP SERIAL NUMBER  (ON TAPE)
C       J                   - CONTRIBUTOR NUMBER INDEX
C       J1, J2, K, L,
C       M1, AND N2          - INDICIES
C       JGTN                - CONTRIBUTOR COUNT TEST NUMBER
C       JIN(J)              - CONTRIBUTOR STATUS
C                                 (-1 - POSSIBLE,  0 - OMIT,  1 - INCLUDE,
C                                   2 - INCLUDE (COEFFICIENT PRESPECIFIED)
C       KDV                 - DEPENDENT VARIABLE INDEX  (PROBLEM NUMBER)
C       KDVD                - DEPENDENT VARIABLE DENOMINATOR IDENTIFICATION
C                                   NUMBER
C       KDVN                - DEPENDENT VARIABLE NUMERATOR IDENTIFICATION
C                                   NUMBER
C       KSFE                - DEPENDENT VARIABLE SCALE FACTOR EXPONENT
C       LCCCN(MC)           - LIST OF ACCEPTED CONTRIBUTOR NUMBERS HAVING
C                                   PRESPECIFIED COEFFICIENTS
C       LCFN(K)             - INPUT LIST OF ACCEPTABLE FUEL CLASS NUMBERS
C       LCGCCN(K,KDV)       - INPUT LIST OF CONTRIBUTOR CODE NUMBERS HAVING
C                                   PRESPECIFIED COEFFICIENTS
C       LCTC(K)             - INPUT LIST OF CONDITIONAL TEST CRITERIA
C       LDVD(KDV)           - INPUT LIST OF DEPENDENT VARIABLE DENOMINATOR
C                                   NUMBERS
C       LDVN(KDV)           - INPUT LIST OF DEPENDENT VARIABLE NUMERATOR
C                                   NUMBERS
C       LFGCCN(K)           - INPUT TAPE LIST OF CONTRIBUTOR CODE NUMBERS
C                                   HAVING POSITIVE COUNTS
C       LGFN(I,K)           - INPUT LIST OF ACCEPTABLE FUEL CLASS-GROUP
C                                 NUMBERS
C       LGTN(J)             - FULL LIST OF CONTRIBUTOR COUNT TEST NUMBERS
C                                 (0 - OMIT, 1 - ACCEPT, 2 - REJECT GROUP IF
C                                 COUNT NOT ZERO, 3 - REJECT GROUP IF COUNT
C                                 ZERO, 4 TO 9 - CONDITIONAL TESTS )
C       LIGTCN(K)           - INPUT LIST OF CONTRIBUTOR NUMBERS HAVING COUNT
C                                 TEST ENTRIES
C       LIGTN(K)            - INPUT LIST OF CONTRIBUTOR COUNT TEST NUMBERS
C       LIPCGC(KDV)         - INPUT LIST OF NUMBER OF ENTRY PAIRS OF
C                                   PRESPECIFIED REGRESSION COEFFICIENTS
C       LIVCN(M)            - LIST OF ACCEPTED INDEPENDENT CONTRIBUTOR
C                                   NUMBERS
C       LMFN(I,K)           - INPUT LIST OF UNACCEPTABLE FUEL CLASS-GROUP-
C                                 MEMBER NUMBERS
C       LOKSFN(N)           - LIST OF ACCEPTED DATA SERIAL NUMBERS
C       LRC(K)              - INPUT LIST OF OVERRIDING INTEGER REGRESSION
C                                   CONTROL DATA
C       LRCC(K)             - LIST OF INTEGER REGRESSION CONTROL DATA
C       LSFN(K)             - INPUT LIST OF ACCEPTABLE DATA NUMBERS
C       M                   - INDEX OF ACCEPTED CONTRIBUTORS WITHOUT
C                                   PRESPECIFIED COEFFICIENTS
C       MC                  - INDEX OF ACCEPTED CONTRIBUTORS WITH
C                                   PRESPECIFIED COEFFICIENTS
C       N                   - INDEX OF ACCEPTED DATA GROUPS
C       NDS                 - ACCEPTABLE DATA SOURCE NUMBER
```

FLAME SPEED REGRESSION CALCULATIONS

```
C                          ( 0 - ALL SOURCES ACCEPTABLE
C                             1,2,ETC - ONLY SOURCES ACCEPTABLE)
C     NEC               - ACCEPTABLE EXPERIMENTAL CONDITIONS NUMBER
C                          ( 0 - ALL SOURCES ACCEPTABLE
C                             1,2,ETC - ONLY SOURCES ACCEPTABLE)
C     NOL(K)            - COLUMN HEADINGS FOR INDEPENDENT CONTRIBUTORS
C                          TABLE
C     NRCI(K)           - INPUT LIST OF OVERRIDING INTEGER REGRESSION
C                            DATA INDICIES
C     NSER              - RUN NUMBER
C     NNZ(K)            - CUMULATIVE SUM OF NON-ZERO VALUES OF
C                            CONTRIBUTOR COUNT INDEX (K)
C     NZ(K)             - CUMULATIVE SUM OF ZERO VALUES OF CONTRIBUTOR
C                            COUNT INDEX (K)
C     OCGNL(MC)         - ACCEPTABLE INDEPENDENT CONTRIBUTOR NAMES
C     OGNL(M)           - NAMES OF ACCEPTED CONTRIBUTORS WITH
C                            PRESPECIFIED COEFFICIENTS
C     OPL(M)            - LIST OF INDEPENDENT CONTRIBUTOR COUNTS
C     PFAIL             - REGRESSION VALIDITY INDICATOR
C                          ( 0.0 - ACCEPTABLE, 1.0 - UNACCEPTABLE )
C     RCCL(K)           - LIST OF DECIMAL REGRESSION CONTROL DATA
C     Y                 - DEPENDENT VARIABLE (BEFORE OR AFTER
C                            COEFFICIENT ADJUSTMENT)
C     YMX(K)            - MAXIMUM ABSOLUTE VALUE OF  Y  ENCOUNTERED
C
      COMMON INT, DEC, IC, J11, J2, J3, NIN, NEX
      DIMENSION INT(10), DEC(10)
      DIMENSION   CGC(50,10), CGCJ(200),  D(6),  DNM(6),  FGCJ(200),
     1 FGCL(90),  FN1L(300),  FN2L(300),  GNL(200),  OCGNL(50),
     2 OGNL(100),  OPL(57),  RCCL(3),  YMX(10),
     3 JIN(200),  LCCCN(50),  LCFN(20),  LCGCCN(50,10),  LCTC(9),
     4 LDVD(10), LDVN(10), LFGCCN(90), LGFN(2,40), LGTN(200),
     5 LIGTCN(50), LIGTN(50), LIPCGC(10), LIVCN(100), LMFN(3,80)  ,
     6 LOKSFN(300),  LRC(11),  LRCC(11),  LSFN(300),  NNZ(9),  NOL(10),
     7 NRCI(11), NZ(9),   COEN(100)
C
C     SETUP OF COLUMN HEADINGS FOR INDEPENDENT CONTRIBUTORS TABLE
C
      DO 19 K=1,10
   19 NOL(K) = K-1
      PFAIL = 0.0
      REWIND 7
      REWIND 8
      REWIND 6
C
C     SETUP FOR SCALE FACTOR CALCULATIONS
C
   20 DO 21 K=1,10
   21 YMX(K) = 0.0
C
C     SETUP OF CONTRIBUTOR STATUS LIST TO -POSSIBLE- CONDITION
C          -1  POSSIBLE,   0  OMIT,   1  INCLUDE,
C           2  INCLUDE (COEFFICIENT PRESPECIFIED)
C
      DO 23 J=1,200
   23 JIN(J) = -1
C
C      READ AND PRINT INPUT DATA
C     GENERAL
C
C      I CARD READING
C
      READ INPUT TAPE 2, 1001
C
C      J CARD READING
C
      READ INPUT TAPE 2, 1006
C
C      K CARD READING
C
      READ INPUT TAPE 2, 1000,
     9            NSER,  IPDV,IPSFN,IPCFN,IPGFN,IPMFN,NDS,NEC,IPIGTN,
     1  IPCTC, IPRCL, IPLRC, IPJ, LAST
      WRITE OUTPUT TAPE 3, 1010,
     9            NSER
      WRITE OUTPUT TAPE 3, 1001
      WRITE OUTPUT TAPE 3, 1011,
     9            NSER, IPDV, IPJ, NDS, NEC, IPSFN, IPCFN
      WRITE OUTPUT TAPE 3, 1012,
     9            IPGFN, IPMFN, IPIGTN, IPCTC, IPRCL, IPLRC
C
C      TEST FOR NO ENTRIES IN DATA SERIAL NUMBER INPUT LIST
C
      IF (IPSFN) 24,30,25
C     PAUSE REMOVED
   24 CONTINUE
C
C      L CARD READING
C
   25 READ INPUT TAPE 2, 1000,
     9            (LSFN(K),K=1,IPSFN)
      WRITE OUTPUT TAPE 3, 1013
      WRITE OUTPUT TAPE 3, 1030,
     9            (LSFN(K),K=1,IPSFN)
C
C      TEST FOR NO ENTRIES IN FUEL CLASS NUMBER INPUT LIST
C
   30 IF (IPCFN) 24,32,31
C
C      M CARD READING
C
   31 READ INPUT TAPE 2, 1000,
     9            (LCFN(K),K=1,IPCFN)
      WRITE OUTPUT TAPE 3, 1014
```

FLAME SPEED REGRESSION CALCULATIONS

```
      WRITE OUTPUT TAPE 3, 1030,
     9             (LCFN(K),K=1,IPCFN)
C
C      TEST FOR NO ENTRIES IN FUEL CLASS-GROUP NUMBER INPUT LIST
C
   32 IF (IPGFN) 24,34,33
C
C      N CARD READING
C
   33 READ INPUT TAPE 2, 1000,
     9             (LGFN(1,K),LGFN(2,K),K=1,IPGFN)
      WRITE OUTPUT TAPE 3, 1015
      WRITE OUTPUT TAPE 3, 1040,
     9             (LGFN(1,K),LGFN(2,K),K=1,IPGFN)
C
C      TEST FOR NO ENTRIES IN FUEL CLASS-GROUP-MEMBER NUMBER INPUT LIST
C
   34 IF (IPMFN) 24,40,35
C
C      O CARD READING
C
   35 READ INPUT TAPE 2, 1000,
     9             (LMFN(1,K),LMFN(2,K),LMFN(3,K),K=1,IPMFN)
      WRITE OUTPUT TAPE 3, 1016
      WRITE OUTPUT TAPE 3, 1039,
     9             (LMFN(1,K),LMFN(2,K),LMFN(3,K),K=1,IPMFN)
C
C      TEST FOR NO ENTRIES IN CONTRIBUTOR TEST INPUT LIST
C
   40 IF (IPIGTN) 24,55,41
C
C      P CARD READING
C
   41 READ INPUT TAPE 2, 1000,
     9             (LIGTCN(K),LIGTN(K),K=1,IPIGTN)
      WRITE OUTPUT TAPE 3, 1017
      WRITE OUTPUT TAPE 3, 1031,
     9             (LIGTCN(K),LIGTN(K),K=1,IPIGTN)
C      SET UP COMPLETE LIST OF CONTRIBUTOR COUNT TEST NUMBERS
C                         - 0 -  OMIT
C                         - 1 -  ACCEPT
C                         - 2 -  REJECT GROUP IF COUNT NOT ZERO
C                         - 3 -  REJECT GROUP IF COUNT ZERO
C                         - 4 TO 9 - CONDITIONAL TESTS
      DO 48 K=1,IPIGTN
      J1 = LIGTCN(K)
      IF (K - IPIGTN) 44,43,42
C     PAUSE REMOVED
   42 CONTINUE
C
C      SET CONTRIBUTOR CODE NUMBER LIMIT
C
   43 J2 = IPJ
      GO TO 45
C
C      REAJUST UPPER LIMIT TO NOT OVERLAP NEXT FIELD
C
   44 J2 = LIGTCN(K+1) - 1
C
C      STORE CONTRIBUTOR COUNT TEST NUMBERS IN SEQUENCE
C
   45 DO 48 J= J1,J2
      LGTN(J) = LIGTN(K)
      IF (LGTN(J)) 46,47,48
C     PAUSE REMOVED
   46 CONTINUE
   47 JIN(J) = 0
   48 CONTINUE
C
C      TEST FOR NO ENTRIES IN CONDITIONAL TEST CRITERIA LIST
C
   50 IF (IPCTC) 24,55,51
   51 IPCTC3 = IPCTC + 3
C
C      Q CARD READING
C
      READ INPUT TAPE 2, 1000,
     9             (LCTC(K),K=4,IPCTC3)
      WRITE OUTPUT TAPE 3, 1018
      WRITE OUTPUT TAPE 3, 1030,
     9             (LCTC(K),K=4,IPCTC3)
C
C      SET UP ESSO REGRESSION CONTROL DATA
C
C      INITIALIZE WITH STANDARD VALUES OF DECIMAL QUANTITIES
C
   55 RCCL(1) = 0.001
      RCCL(2) = 0.00002
      RCCL(3) = 0.00001
C
C      INITIALIZE WITH STANDARD VALUES OF INTEGER QUANTITIES
C
      DO 56 K=4,11
   56 LRCC(K) = 1
      LRCC(5) = 0
      LRCC(10) = 0
C
C      TEST FOR NO ENTRIES IN DECIMAL OVERRIDE LIST
C
      IF (IPRCL)24,58,57
C
C      R CARD READING
C
C      SUBSTITUTE OVERRIDING DECIMAL VALUES
```

FLAME SPEED REGRESSION CALCULATIONS

```
C
   57 READ INPUT TAPE 2, 2001,
     9              (RCCL(K),K=1,3)
C
C     TEST FOR NO ENTRIES IN INTEGER OVERRIDE LIST
C
   58 IF (IPLRC) 24,61,59
C
C     S CARD READING
C
   59 READ INPUT TAPE 2, 1000,
     9              (NRCI(K),LRC(K),K=1,IPLRC)
C
C     SUBSTITUTE OVERIDING INTEGER VALUES
C
      DO 60 K=1,IPLRC
      L = NRCI(K)
   60 LRCC(L) = LRC(K)
C
C     PRINTOUT OF ESSO REGRESSION CONTROL NUMBER LIST
C
   61 WRITE OUTPUT TAPE 3, 1019
      WRITE OUTPUT TAPE 3, 1032,
     9              (RCCL(K),K=1,3),(LRCC(K),K=4,11)
C
C     SET UP LIST OF DEPENDENT VARIABLE CODE NUMBERS AND NUMBER OF
C          CORRESPONDING PRESPECIFIED REGRESSION COEFFICIENTS
C
   65 DO 67 KDV = 1,IPDV
C
C     T CARD READING
C
      READ INPUT TAPE 2, 1000,
     9              LDVN(KDV),LDVD(KDV),LIPCGC(KDV)
C
C     TEST FOR NO PRESPECIFIED REGRESSION COEFFICIENTS
C
      IF (LIPCGC(KDV)) 24,67,66
   66 IPCGC = LIPCGC(KDV)
C
C     U CARD ASSIGNMENTS
C
  660 CALL INPUT
      M = 0
      LIMIT = 10*IC
      IGO = LIMIT - 9
      IF ( LIMIT - IPCGC) 662, 662, 661
  661 LIMIT = IPCGC
  662 DO 663 K = IGO, LIMIT
      M = M + 1
      LCGCCN(K,KDV) = INF(M)
  663 CGC(K, KDV)    = DEC(M)
      IF ( LIMIT - IPCGC) 660, 67, 67
   67 CONTINUE
C
C     START OF FIRST TAPE 6 PASS
C
C     HEADING READING
C
  100 READ INPUT TAPE 6, 1002
C
C     INDIVIDUAL DATA GROUP READING
C
      READ INPUT TAPE 6, 1003, IPI
      D(1) = 1.0
      N = 0
      DO 190 I=1,IPI
      READ  INPUT TAPE 6, 1004,
     9              ISFN,FN1,FN2,ICFN,IGFN,IMFN,INDS,INEC,(D(K),K=2,6)
     1 ,IPFGC,(LFGCCN(K),FGCL(K),K=1,IPFGC)
C
C     TEST FOR DATA GROUP SERIAL NUMBER SEQUENCE
C
      IF (I - ISFN) 104,106,104
C      PAUSE REMOVED
  104 CONTINUE
C
C     TEST FOR LIMIT OF 300 ACCEPTABLE DATA GROUPS
C
  106 IF (N-300) 110,107,105
C      PAUSE REMOVED
  105 CONTINUE
  107 PFAIL = 3.0
      GO TO 190
C
C     START TESTING SEQUENCE FOR ACCEPTABLE REGRESSION DATA
C
  110 IF (IPSFN) 111,120,112
C      PAUSE REMOVED
  111 CONTINUE
C
C     TEST FOR UNACCEPTABLE DATA GROUP SERIAL NUMBERS
C
  112 DO 113 K = 1,IPSFN
      IF (I - LSFN(K)) 113,190,113
  113 CONTINUE
  120 IF (IPCFN) 111,123,121
C
C     TEST FOR ACCEPTABLE FUEL CLASS NUMBER
C
  121 DO 122 K=1,IPCFN
      IF (ICFN - LCFN(K)) 122,123,122
  122 CONTINUE
      GO TO 190
```

FLAME SPEED REGRESSION CALCULATIONS

```
  123 IF (IPGFN) 111,126,124
C
C       TEST FOR ACCEPTABLE FUEL CLASS-GROUP NUMBERS
C
  124 DO 125 K=1,IPGFN
      IF (ICFN-LGFN(1,K)) 125,1241,125
 1241 IF (IGFN-LGFN(2,K)) 125,126,125
  125 CONTINUE
      GO TO 190
  126 IF (IPMFN) 111,130,127
C
C       TEST FOR ACCEPTABLE FUEL CLASS-GROUP-MEMBER NUMBERS
C
  127 DO 128 K=1,IPMFN
      IF (ICFN-LMFN(1,K)) 128,1271,128
 1271 IF (IGFN-LMFN(2,K)) 128,1272,128
 1272 IF (IMFN-LMFN(3,K)) 128,190,128
  128 CONTINUE
  130 IF (NDS) 111,135,131
C
C       TEST FOR ACCEPTABLE DATA SOURCE NUMBER
C
  131 IF (INDS - NDS) 190,135,190
  135 IF (NEC) 111,140,136
C
C       TEST FOR ACCEPTABLE EXPERIMENTAL CONDITIONS NUMBER
C
  136 IF (INEC - NEC) 190,140,190
C
C       TEST FOR AN UNDEFINED DEPENDENT VARIABLE
C             (UNACCEPTABLE IF EITHER NUMERATOR OR DENOMINATOR ZERO)
C
  140 DO 142 KDV=1,IPDV
      K = LDVN(KDV)
      IF (D(K)) 141,190,141
  141 K = LDVD(KDV)
      IF (D(K)) 142,190,142
  142 CONTINUE
  150 IF (IPIGIN) 111,180,151
C
C       TEST FOR CONTRIBUTOR COUNT TESTS
C
  151 DO 152 J=1,IPJ
  152 FGCJ(J) = 0.0
      DO 153 K=1,IPFGC
      J = LFGCCN(K)
C
C       STORE CONTRIBUTOR NUMBERS FROM GROUP BEING TESTED
C
  153 FGCJ(J) = FGCL(K)
      DO 154 K=4,9
      NZ(K) = 0
  154 NNZ(K) = 0
C
C       OPERATIONS ON CONTRIBUTOR COUNT TEST NUMBERS
C
      DO 165 J = 1,IPJ
      JGTN = LGTN(J)
C
C       CONTRIBUTOR COUNT TEST  2  - ONLY ZERO COUNTS ACCEPTED
C
      IF (JGTN - 2) 165,156,157
  156 IF (FGCJ(J)) 190,165,190
C
C       CONTRIBUTOR COUNT TEST  3  - ONLY NON-ZERO COUNTS ACCEPTED
C       CONTRIBUTOR COUNT TESTS 4 TO 9
C
  157 IF (JGTN - 3) 158,159,160
C       PAUSE REMOVED
  158 CONTINUE
  159 IF (FGCJ(J)) 165,190,165
  160 IF (FGCJ(J)) 161,162,161
C
C       SUM OF NON-ZERO VALUES OF INDEX (JGTN)
C
  161 NNZ(JGTN) = NNZ(JGTN) + 1
      GO TO 165
C
C       SUM OF ZERO VALUES OF INDEX (JGTN)
C
  162 NZ(JGTN) = NZ(JGTN) + 1
  165 CONTINUE
      IF (IPCTC) 111,180,171
C
C       TEST FOR CONDITIONAL CONTRIBUTOR COUNT TESTS
C
  171 DO 175 K=4,IPCTC3
      IF (LCTC(K)) 172,175,173
  172 IF (NZ(K) + LCTC(K)) 190,175,175
  173 IF (NNZ(K) - LCTC(K)) 190,175,175
  175 CONTINUE
C
C       CALCULATIONS ON ACCEPTABLE DATA GROUPS
C
  180 DO 182 K=1,IPFGC
      J = LFGCCN(K)
C
C       JIN(J) EITHER  -1 OR 0
C
      IF (JIN(J) + 1) 182,181,182
  181 JIN(J) = 1
  182 CONTINUE
      N = N + 1
      LOKSFN(N) = I
```

FLAME SPEED REGRESSION CALCULATIONS

```
C
C     SETUP OF DESIRED DEPENDENT VARIABLE
C
      DO 189 KDV = 1,IPDV
      KDVN = LDVN(KDV)
      KDVD = LDVD(KDV)
      Y = D(KDVN)/D(KDVD)
      IPCGC = LIPCGC(KDV)
C
C     TEST FOR NO PRESPECIFIED COEFFICIENTS
C
      IF (IPCGC) 111,189,184
  184 DO 188 K=1,IPFGC
      J = LFGCCN(K)
C
C     TEST ONLY THOSE CONTRIBUTORS WHICH ARE NOT TO BE OMITTED
C
      IF (JIN(J) - 1) 188,185,188
  185 DO 186 L= 1,IPCGC
C
C     TEST EACH CONTRIBUTOR IN GROUP
C
      IF (J - LCGCCN(L,KDV)) 186,187,186
  186 CONTINUE
      GO TO 188
C
C     ADJUST VALUE OF DEPENDENT VARIABLE
C
  187 Y = Y - CGC(L,KDV)*FGCL(K)
  188 CONTINUE
C
C     DETERMINE MAXIMUM VALUE OF  Y  FOR SCALING TO FIT ESSO OUTPUT
C
  189 YMX(KDV) = MAX1F(YMX(KDV),ABSF(Y))
      FN1L(N) = FN1
      FN2L(N) = FN2
  190 CONTINUE
      IPN = N
      READ INPUT TAPE 6, 1005, (GNL(J),J=1,200)
      READ INPUT TAPE 6, 1005, (DNM(K),K=1,6)
      REWIND 6
C
C     END OF FIRST TAPE 6 PASS
C
C     TEST FOR NO ACCEPTABLE DATA
C
      IF (IPN) 191,191,192
C
C     DIAGNOSTIC        - NO DATA ACCEPTABLE - PROCESS NEXT RUN
C
  191 WRITE OUTPUT TAPE 3, 1025
      GO TO 302
C
C     PRINT LIST OF ACCEPTABLE DATA SERIAL NUMBER AND FUEL NAMES
C
  192 LKCC(3) = IPN
      WRITE OUTPUT TAPE 3, 1022
  193 WRITE OUTPUT TAPE 3, 1034,
     9               (LOKSFN(N), FN1L(N), FN2L(N), N=1, IPN)
C
C     TEST FOR DIAGNOSTIC PRINTOUT - FIRST 300 DATA GROUPS USED
C
      IF (PFAIL - 3.0) 200,194,200
  194 WRITE OUTPUT TAPE 3, 1027
      PFAIL = 0.0
C
C     GENERATION OF ESSO REGRESSION INPUT DATA
C
C     SET UP DEPENDENT VARIABLE
C
  200 DO 300 KDV=1,IPDV
      KDVN = LDVN(KDV)
      KDVD = LDVD(KDV)
      IPCGC = LIPCGC(KDV)
      IF (IPCGC) 24,210,206
  206 DO 207 J=1,IPJ
  207 CGCJ(J) = 0.0
C
C     SET UP LIST OF PRESPECIFIED COEFFICIENTS
C
      DO 209  K = 1,IPCGC
      J = LCGCCN(K,KDV)
      CGCJ(J) = CGC(K,KDV)
      IF (JIN(J) - 1) 209,208,209
C
C     SET JIN(J) = 2 FOR CONTRIBUTORS WITH SPECIFIED COEFFICIENTS ONLY
C
  208 JIN(J) = 2
  209 CONTINUE
C
C     DETERMINE NUMBER OF INDEPENDENT VARIABLES FOR REGRESSION
C
  210 M = 0
      MC = 0
      DO 213 J=1,IPJ
C
C     TEST FOR STATUS OF CONTRIBUTOR
C
      IF (JIN(J) - 1) 213,211,212
C
C     INCREMENT NUMBER OF DEPENDENT VARIABLES INDEX
C
  211 M = M + 1
      LIVCN(M) = J
```

FLAME SPEED REGRESSION CALCULATIONS

```
      OGNL(M) = GNL(J)
      GO TO 213
C
C      INCREMENT NUMBER OF PRESPECIFIED COEFFICIENTS INDEX
C
  212 MC = MC + 1
      OCGNL(MC) = GNL(J)
      LCCCN(MC) = J
  213 CONTINUE
      IPM = M
      IPMC = MC
C
C      TEST FOR EXCEEDING LIMIT OF DEPENDENT VARIABLES COUNT OF ESSO
C           REGRESSION PROGRAM
C
      IF (IPM-57) 220,220,216
  216 PFAIL = 1.0
      GO TO 260
C
C      FINAL MAKEUP OF ESSO REGRESSION CONTROL DATA
C
  220 LRCC(1) = KDV
      LRCC(2) = IPM + 1
      LRCC(3) = IPN
C
C      WRITE TITLE AND CONTROL DATA FOR REGRESSION ANALYSIS
C
      WRITE OUTPUT TAPE 7, 1006
      WRITE OUTPUT TAPE 7, 1007, (RCCL(K),K=1,3), (LRCC(K),K=1,11)
C
C      START OF SECOND TAPE 6 PASS
C
      READ INPUT TAPE 6, 1002
      READ INPUT TAPE 6, 1003, IPI
C
C      CALCULATION OF DEPENDENT VARIABLE SCALE FACTOR
C
      KSFE = 0
C
C      REDUCE POWER OF 10 UNTIL  YMX  LESS THAN 1000.
C
  221 IF (YMX(KDV) - 1000.) 223,222,222
  222 YMX(KDV) = YMX(KDV)/10.0
      KSFE = KSFE + 1
      GO TO 221
C
C      INCREASE POWER OF 10 UNTIL  YMX  GREATER THAN 100.
C
  223 IF (YMX(KDV) - 100.0) 224,230,230
  224 KSFE = KSFE - 1
      YMX(KDV) = 10.0*YMX(KDV)
      GO TO 223
C
C      CHOOSE ACCEPTABLE DATA GROUPS FROM TAPE
C
  230 DO 255 N = 1,IPN
  231 READ  INPUT TAPE 6, 1004,
     9              ISFN,FN1,FN2,ICFN,IGFN,IMFN,INDS,INEC,(D(K),K=2,6)
     1  ,IPFGC,(LFGCCN(K),FGCL(K),K=1,IPFGC)
C
C      TEST FOR ACCEPTABLE SERIAL NUMBERS
C
      IF (ISFN - LOKSFN(N)) 231,235,232
C      PAUSE REMOVED
  232 CONTINUE
  235 DO 236 J = 1,IPJ
  236 FGCJ(J) = 0.0
      DO 237 K = 1,IPFGC
      J = LFGCCN(K)
  237 FGCJ(J) = FGCL(K)
C
C      PREPARE LIST OF INDEPENDENT CONTRIBUTOR COUNTS
C
      DO 238 M = 1,IPM
      J = LIVCN(M)
  238 OPL(M) = FGCJ(J)
C
C      CALCULATION OF DEPENDENT VARIABLE
C
  240 Y = D(KDVN)/D(KDVD)
C
C      TEST FOR NO PRESPECIFIED COEFFICIENTS
C
      IF (IPMC) 241,250,242
C      PAUSE REMOVED
  241 CONTINUE
  242 DO 243 MC = 1,IPMC
      J = LCCCN(MC)
C
C      DEPENDENT VARIABLE ADJUSTMENT FROM PRESPECIFIED COEFFICIENTS
C
  243 Y = Y - CGCJ(J)*FGCJ(J)
C
C      DEPENDENT VARIABLE SCALING
C
  250 Y = Y*10.0**(-KSFE)
C
C      WRITE DATA FOR REGRESSION ANALYSIS
C
      WRITE OUTPUT TAPE 7, 1008, ISFN, (OPL(M),M=1,IPM),Y
  255 CONTINUE
      REWIND 6
C
C      END OF SECOND TAPE 6 PASS
```

FLAME SPEED REGRESSION CALCULATIONS

```
C
C       PRINTOUT OF SUCCESSFUL DATA PREPARATION INFORMATION
C
  260 WRITE OUTPUT TAPE 3, 1010,
     9             NSER
      WRITE OUTPUT TAPE 3, 10101,
     9             KDV
      WRITE OUTPUT TAPE 3, 1020 ,
     9             KSFE,DNM(KDVN),DNM(KDVD)
      IF (IPCGC) 24,262,261
  261 WRITE OUTPUT TAPE 3, 1021  ,
     9             IPMC
      WRITE OUTPUT TAPE 3, 1033,
     9             (LCGCCN(K,KDV),CGC(K,KDV),K=1,IPCGC)
C
C       TEST FOR NO INDEPENDENT VARIABLES
C
  262 IF (IPM) 270,270,263
C
C       PRINTOUT OF INDEPENDENT CONTRIBUTORS WITH THEIR REGRESSION
C             INDICIES
C
  263 WRITE OUTPUT TAPE 3, 1023
      WRITE OUTPUT TAPE 3, 1035,
     9             (NOL(K),K=1,10)
C
C       PRINT OUT FIRST 9
C
      M2 = XMINOF(9,IPM)
      WRITE OUTPUT TAPE 3, 1036,
     9             (LIVCN(M),OGNL(M), M=1,M2)
      IF (IPM - 9) 270,270,265
  265 LNX = IPM/10
C
C       PRINT OUT IN SEQUENCES OF 10
C
      DO 266 LN = 1,LNX
      M1 = 10*LN
      M2 = XMINOF (M1+9,IPM)
  266 WRITE OUTPUT TAPE 3, 1037,
     9             M1,(LIVCN(M),OGNL(M), M=M1,M2)
  270 IF (IPMC) 280,280,271
C
C       PRINTOUT OF NAMES OF CONTRIBUTORS WHICH HAVE PRESPECIFIED
C             COEFFICIENTS
C
  271 WRITE OUTPUT TAPE 3, 1024
      LNX = 1 + (IPMC - 1)/10
      DO 272 LN=1,LNX
      MC1 = 10*LN - 9
      MC2 = XMINOF( MC1+9,IPMC)
  272 WRITE OUTPUT TAPE 3, 1038,
     9             (LCCCN(MC), OCGNL(MC), MC=MC1,MC2)
  280 IF (PFAIL - 1.0) 290,281,290
C
C       DIAGNOSTIC        - CAPACITY OF REGRESSION ROUTINE EXCEEDED
C
  281 WRITE OUTPUT TAPE 3, 1026
      PFAIL  = 0.0
      GO TO 2901
  290 PFAIL = 0.0
      REWIND 7
C
      INTAPE = 7
C       CALL ESSO REGRESSION PROGRAM
C
      CALL ESSO4 ( INTAPE)
 2901 DO 300 J= 1, IPJ
      IF (JIN(J) - 2) 300,292,291
C       PAUSE REMOVED
  291 CONTINUE
  292 JIN(J) = 1
  300 CONTINUE
C
C       TEST FOR END OF CALCULATIONS
C
  302 IF(LAST)301,20,301
  301 REWIND 7
      REWIND 6
      WRITE OUTPUT TAPE 3, 2000
      GO TO 20
C
C       FORMAT STATEMENTS
C
 1000 FORMAT ( 18I4)
 1001 FORMAT (72H
     1                      )
 1002 FORMAT (72H
     1                      )
 1003 FORMAT  (1H0 6I6 )
 1004 FORMAT
     9 (1H0 I6,2A6,5I6,1P5E12.4,I67(1H I6,E12.4,I6,E12.4,I6,E12.4,I6,
     1E12.4,I6,E12.4,I6,E12.4))
 1005 FORMAT
     9 (1H0 9(6X,A6)/(1H 6X,A6,6X,A6,6X,A6,6X,A6,6X,A6,6X,A6,6X,A6,6X,
     1A6,6X,A6))
 1006 FORMAT (72H
     1                      )
 1007 FORMAT  ( 3F10.5,3I5,I3,7I2)
 1008 FORMAT  ( I7,5X,1P5E12.4 / (6E12.4))
 1010 FORMAT
     9 (1H1, 3X,  98HMONSANTO RESEARCH CORPORATION FLAME SPEED REGRESSIO
     1N  -   ROUTINE 1922   - MODIFICATION 1 -    RUN 14)
10101 FORMAT
```

FLAME SPEED REGRESSION CALCULATIONS

```
    9 (1H+,107X   8HPROBLEM  I4 )
1011 FORMAT(1H03X5HRUN  I4,17X   32HNUMBER OF PROBLEMS IN THIS RUN  I4,
    1       7X, 40HHIGHEST CONTRIBUTOR CODE NUMBER IN USE    I7 /
    2 1H0  29X, 31HACCEPTABLE DATA SOURCE NUMBER     I5,
    3       7X, 43HACCEPTABLE EXPERIMENTAL CONDITIONS NUMBER   I4 /
    4 1H0  37X, 44HENTRIES TO BE READ FROM THE INPUT DATA CARDS   /
    5 1H0   3X,  9HCARD TYPE   5X, 17HNUMBER OF ENTRIES
    6      20X, 17HLIST SIGNIFICANCE   /
    7 1H0   6X,  3H-L- 14X,I4,  8X,  40H- UNACCEPTABLE DATA GROUP SERIA
    8L NUMBERS       /
    9 1H ,  6X,   3H-M- 14X,I4, 8X,31H- ACCEPTABLE FUEL CLASS NUMBERS )
1012 FORMAT
    9 ( 1H , 6X,  3H-N- 14X,I4, 8X, 37H- ACCEPTABLE FUEL CLASS-GROUP NU
    1MBERS /1H ,6X,3H-O-,14X,I4,8X, 46H- UNACCEPTABLE FUEL-CLASS-GROUP-
    2MEMBER NUMBERS  /
    3  1H , 6X,  3H-P- 14X,I4, 8X, 32H- CONTRIBUTOR COUNT TEST NUMBERS
    4/  1H , 6X,  3H-Q- 14X,I4, 8X, 33H- CONDITIONAL COUNT TEST CRITERI
    5A /1H , 6X,  3H-R- 14X,I4, 8X, 44H- OVERRIDING DECIMAL REGRESSION
    6CONTROL DATA  /
    7  1H , 6X,  3H-S- 14X,I4, 8X, 44H- OVERRIDING INTEGER REGRESSION
    8CONTROL DATA  )
1013 FORMAT
    9 (1H1, 10X, 46HLIST OF UNACCEPTABLE DATA GROUP SERIAL NUMBERS /)
1014 FORMAT
    9 (1H0, 10X, 37HLIST OF ACCEPTABLE FUEL CLASS NUMBERS  /)
1015 FORMAT
    9 (1H0, 10X, 43HLIST OF ACCEPTABLE FUEL CLASS-GROUP NUMBERS / )
1016 FORMAT
    9 (1H0, 10X, 52HLIST OF UNACCEPTABLE FUEL CLASS-GROUP-MEMBER NUMBER
    1S /)
1017 FORMAT
    9 (1H0, 10X, 31HLIST OF CONTRIBUTOR COUNT TESTS /)
1018 FORMAT
    9 (1H0, 10X, 27HLIST OF COUNT TEST CRITERIA  /)
1019 FORMAT
    9 (1H0, 10X, 28HESSO REGRESSION CONTROL LIST /)
1020 FORMAT
    9 (1H0,48X, I3 /
    1  1H ,10X, 21HDEPENDENT VARIABLE = A6,1H/ A6, 4H X10  )
1021 FORMAT
    9 (1H0,10X, 6HMINUS I4, 32H  CONTRIBUTIONS OF THE FOLLOWING  /
    1  1H ,10X,69HLIST OF CONTRIBUTOR CODE NUMBERS WITH THEIR PRESPECIF
    2IED COEFFICIENTS     /)
1022 FORMAT
    9 (1H1, 10X, 51HLIST OF ACCEPTED DATA SERIAL NUMBERS AND FUEL NAMES
    1 / )
1023 FORMAT
    9 (1H0, 10X, 77HLIST OF INDEPENDENT CONTRIBUTORS WITH THEIR CORRESP
    1ONDING REGRESSION INDICIES /)
1024 FORMAT
    9 (1H0, 10X, 53HLIST OF CONTRIBUTORS HAVING PRESPECIFIED COEFFICIEN
    1TS  /)
1025 FORMAT
    9 (1H0, 10X, 18HNO ACCEPTABLE DATA )
1026 FORMAT
    9 (1H0, 10X, 39HCAPACITY OF REGRESSION ROUTINE EXCEEDED )
1027 FORMAT
    9 (1H0, 10X, 46HONLY THE FIRST 300 ACCEPTABLE DATA GROUPS USED )
1030 FORMAT
    9 (1H , 10X, 18I6)
1031 FORMAT
    9 (1H , 10X, I6,I3,I6,I3,I6,I3,I6,I3,I6,I3,I6,I3,I6,I3,I6,I3,I6,I3,
    1I6,I3,I6,I3,I6,I3 )
1032 FORMAT
    9 (1H , 10X  3(F10.5,3X), 10X, I4, 7I3 )
1033 FORMAT
    9 (1H , 11X, I6,1PE12.4, I6,E12.4, I6,E12.4, I6,E12.4, I6,E12.4,
    1              I6,E12.4 )
1034 FORMAT
    9 (1H , 11X, I5,1X,2A6,I5,1X,2A6, I5,1X,2A6, I5,1X,2A6,
    1              I5,1X,2A6, I5,1X,2A6 )
1035 FORMAT
    9 (1H ,  5X, I9, 9I11)
1036 FORMAT
    9 (1H , 20X, 9(I4,1X,A6))
1037 FORMAT
    9 (1H , I2,7X,10(I4,1X,A6))
1038 FORMAT
    9 (1H , 9X, 10(I4,1X,A6))
1039 FORMAT
    9 (1H , 10X, I4,3H / I2,3H / I2, I8,3H / I2,3H / I2,
    1              I8,3H / I2,3H / I2, I8,3H / I2,3H / I2,
    2              I8,3H / I2,3H / I2, I8,3H / I2,3H / I2  )
1040 FORMAT
    9 (1H , 10X, I4,3H / I3,  I8,3H / I3, I8,3H / I3, I8,3H / I3,
    1              I8,3H / I3,  I8,3H / I3, I8,3H / I3, I8,3H / I3  )
2000 FORMAT(1H0, 25X,  20HEXECUTION COMPLETED       )
2001 FORMAT ( 3F10.5 )
     END
```

SUBROUTINE ESSO4

MULTIPLE LINEAR REGRESSION CALCULATIONS

```
*       LIST8
*       SYMBOL TABLE
CESSO2       ESSO REGRESSION SUBROUTINE  MOD 4
C        PRESPECIFIED INPUT FORMAT   6F12.5
C           VARIABLE INPUT TAPE SPECIFICATIONS
      SUBROUTINE ESSO4 ( INTAPE)
      DIMENSION DATA(60),VECTOR(60,60),AVE(60),SIGMA(60),COEN(60),SIGMCO
     1(60),INDEX(60)
      DIMENSION RATIO(60) ,DEC( 101),  FMT(120)  , HEAD(12)
      REWIND INTAPE
      READ INPUT TAPE INTAPE, 4000,(HEAD(I),I=1,12)
      READ INPUT TAPE INTAPE,        5,
     9                   TOL,EFIN,EFOUT,NOPROB,INVAR,NODATA,IFWT,IFSTEP
     1,IFRAW,IFAVE,IFRESD,IFCOEN,IFPRED,IFCNST
      INDATA = 1
      NRUNSE = 1
      IDEPSE = INVAR + 1
      IWEIGT =  INVAR + 2
      GO TO ( 101, 102),INDATA
  101 WRITE OUTPUT TAPE 3, 5003,(HEAD(I), I = 1, 12)
      WRITE OUTPUT TAPE 3,
     9          6,  TOL,        EFIN,EFOUT,NOPROB,INVAR,NODATA,IFWT,IFSTEP
     1,IFRAW,IFAVE,IFRESD,IFCOEN,IFPRED,IFCNST
  102 DO 4020 I=1,INVAR
 4020 COEN(I)=0.0
C     IFWT = 1,THEN ALL WHTS = 1.0
C     IFSTEP = 1, DO NOT PRINT EACH STEP
C     IFRAW  = 1   DO NOT PRINT RAW SUMS AND SQUARES
C     IFAVE  = 1   DO NOT PRINT AVERAGES
C     IFRESD = 1   DO NOT PRINT RESIDUAL SUMS SQUARES
C     IFCOEN = 1   DO NOT PRINT PARTIAL COEFFICIENTS
C     IFPRED = 1   DO NOT CALC PREDICTED VALUES
C     IFCNST = 1   DO NOT HAVE CONST TERM IN EQUATION
C     INDATA = 1,  LIST INPUT DATA ON TAPE 3
      NOIN = 0
      VAR  = 0
      K    = 0
      FLEVEL = 0
      NOENT = 0
      NOMIN = 0
      NUMAX = 0
      NOVAR = INVAR
      NVP1 = NOVAR + 1
  110 DO 120 I = 1, NVP1
  130 DO 120 J = 1, NVP1
  120 VECTOR(I,J) = 0.0
  121 REWIND 8
  140 IF(IFWT) 900, 500, 150
  900 WRITE OUTPUT TAPE 3, 905
      GO TO 910
  150 INPUT = NOVAR + 1
      DO 170 N = 1, NODATA
  160 READ INPUT TAPE INTAPE,5000, (DEC(I), I =1, INPUT )
      J1 = 1
      RUN  = DEC(NRUNSE)
      DATA(NOVAR) = DEC(IDEPSE)
      DO 1613 J= 1, INPUT
      IF( J - NRUNSE)1611,1613,1611
 1611 IF( J - IDEPSE)1612,1613,1612
 1612 DATA(J1) = DEC(J)
      J1 = J1 +1
 1613 CONTINUE
  161 WRITE TAPE 8,(DATA(L), L = 1, NOVAR),RUN
      GO TO ( 162, 180),INDATA
  162 WRITE OUTPUT TAPL 3,
     9          11,  RUN, ( DATA(L) , L = 1, NOVAR )
  180 DO 190 I = 1, NOVAR
  200 VECTOR(I, NOVAR + 1) = VECTOR(I, NOVAR + 1) + DATA(I)
  210 DO 220 J = 1, NOVAR
  220 VECTOR (I,J) = VECTOR(I,J) + DATA(I) * DATA(J)
  190 CONTINUE
  170 VECTOR(NVP1, NVP1)              = VECTOR(NVP1, NVP1)           + 1.0
  230 GO TO 565
C     CALCULATION SUMS WHEN VARIABLE WEIGHTS
  500 INPUT = NOVAR +2
      DO 510 N = 1, NODATA
  520 READ INPUT TAPE INTAPE,5000 ,(DEC(I), I=1, INPUT)
      J1=1
      RUN  = DEC(NRUNSE)
      DATA(NOVAR) = DEC(IDEPSE)
      WHT  = DEC(IWEIGT)
      DO 5204  J=1, INPUT
      IF( J - NRUNSE) 5201, 5204, 5201
 5201 IF( J - IDEPSE) 5202, 5204, 5202
 5202 IF( J - IWEIGT) 5203, 5204, 5203
 5203 DATA(J1) = DEC(J)
      J1 = J1+1
 5204 CONTINUE
  521 WRITE TAPE 8,(DATA(L), L = 1, NOVAR),RUN
      GO TO ( 522, 530),INDATA
  522 WRITE OUTPUT TAPE 3,
     9          11,  RUN, ( DATA(L) , L = 1, NOVAR )
  530 DO 540 I = 1, NOVAR
  550 VECTOR (I,NOVAR + 1) = VECTOR (I, NOVAR + 1) + DATA (I) * WHT
  560 DO 540 J = 1, NOVAR
  540 VECTOR (I, J) = VECTOR (I, J) + DATA (I) * DATA (J) * WHT
  510 VECTOR (NVP1, NVP1)             = VECTOR (NVP1, NVP1)          +WHT
C     COMPLETED SUMS OF SQUARES AND CROSS PRODUCTS.  THESE ARE IN
C    1STORAGE IN LOCATION, VECTOR (I, J).  THESE WILL BE PRINTED OUT ON
C    2TAPE 3 UNDER CONTROL OF STATEMENT 100
  565 NOVM1 = NOVAR - 1
  566 NOVPL = NOVAR + 1
      REWIND INTAPE
      WRITE OUTPUT TAPE 3, 5003,(HEAD(I), I = 1, 12)
```

SUBROUTINE ESS04

(CONTINUED)

MULTIPLE LINEAR REGRESSION CALCULATIONS

```
  567 WRITE OUTPUT TAPE 3, 90, NOPROB, NODATA, NOVAR, VECTOR(NOVPL,       ESS04
     1NOVPL).EFIN, EFOUT                                                   ESS04
  570 GO TO 4003                                                          ESS04
 4003 IF(IFRAW) 900,580,650                                               ESS04
  580 WRITE OUTPUT TAPE 3, 15                                             ESS04
  590 WRITE OUTPUT TAPE 3, 20, (I, VECTOR (I, NOVPL), I = 1, NOVMI)       ESS04
  600 WRITE OUTPUT TAPE 3, 25, VECTOR (NOVAR, NOVPL)                      ESS04
  610 WRITE OUTPUT TAPE 3, 30                                             ESS04
  620 WRITE OUTPUT TAPE 3, 35,((I,J, VECTOR(I,J), J=I,NOVMI),I=1,NOVMI)   ESS04
  630 WRITE OUTPUT TAPE 3, 40, (I, VECTOR(I,NOVAR),I=1,NOVMI)             ESS04
  640 WRITE OUTPUT TAPE 3, 45, VECTOR (NOVAR, NOVAR)                      ESS04
      GO TO 650                                                           ESS04
C     CALCULATION OF RESIDUAL SUMS OF SQUARES AND CROSS PRODUCTS          ESS04
  650 IF(IFCNST) 900,651,735                                              ESS04
  651 IF(VECTOR(NOVPL,NOVPL)) 652,652,655                                 ESS04
  652 WRITE OUTPUT TAPE 3, 654                                            ESS04
      GO TO 910                                                           ESS04
  655 DO 660 I = 1, NOVAR                                                 ESS04
  670 DO 660 J = I, NOVAR                                                 ESS04
  660 VECTOR (I,J) = VECTOR (I,J) - (VECTOR(I,NOVPL) * VECTOR (J,NOVPL)   ESS04
     - / VECTOR (NOVPL, NOVPL))                                           ESS04
  680 DO 690  I = 1, NOVAR                                                ESS04
  690 AVE(I)  = VECTOR(I,NOVPL) / VECTOR(NOVPL,NOVPL)                     ESS04
  700 IF (IFAVE)    900, 710, 735                                         ESS04
  710 WRITE OUTPUT TAPE 3, 50                                             ESS04
  720 WRITE OUTPUT TAPE 3, 20, (I, AVE(I), I = 1, NOVMI)                  ESS04
  730 WRITE OUTPUT TAPE 3, 25, AVE(NOVAR)                                 ESS04
  735 IF (IFRESD)  900, 740, 760                                          ESS04
  740 WRITE OUTPUT TAPE 3, 55                                             ESS04
  750 WRITE OUTPUT TAPE 3, 35, ((I,J, VECTOR(I,J),J=I,NOVMI),I=1,NOVMI)   ESS04
  760 WRITE OUTPUT TAPE 3, 40, (I,VECTOR(I,NOVAR),I=1,NOVMI)              ESS04
  770 WRITE OUTPUT TAPE 3, 45, VECTOR(NOVAR,NOVAR)                        ESS04
  780 NOSTEP = -1                                                         ESS04
  781 ASSIGN  1320  TO NUMBER                                             ESS04
  782 DEFR    = VECTOR(NOVPL,NOVPL) - 1.0                                 ESS04
  790 DO 800  I = 1,NOVAR                                                 ESS04
  791 IF(VECTOR(I,I)) 792,794,810                                         ESS04
  792 WRITE OUTPUT TAPE 3, 793,                                           ESS04
     9          I                                                         ESS04
      GO TO 910                                                           ESS04
  793 FORMAT (31H ERROR RESIDUAL SQUARE VARIABLE I4,31H IS NEGATIVE,PROB  ESS04
     1LEM TERMINATED )                                                    ESS04
  794 WRITE OUTPUT TAPE 3,795,  I                                         ESS04
  796 SIGMA(I) =       1.0                                                ESS04
  797 GO TO 800                                                           ESS04
  795 FORMAT(1H0I0H VARIABLE I5,12H IS CONSTANT )                         ESS04
  810 SIGMA(I) = SQRTF (VECTOR (I,I))                                     ESS04
  800 VECTOR(I,I) = 1.0                                                   ESS04
  820 DO 830  I = 1,NOVMI                                                 ESS04
  840 IP1 = I + 1                                                         ESS04
  841 DO 830 J = IP1, NOVAR                                               ESS04
  850 VECTOR(I,J) = VECTOR(I,J) /( SIGMA(I)* SIGMA(J))                    ESS04
  830 VECTOR(J,I) = VECTOR(I,J)                                           ESS04
  860 IF (IFCOEN)  900, 870, 1000                                         ESS04
  870 WRITE OUTPUT TAPE 3, 60                                             ESS04
  874 NOVM2  = NOVMI  - 1                                                 ESS04
  875 DO 885  I = 1, NOVM2                                                ESS04
  880 IP1 =  I + 1                                                        ESS04
  885 WRITE OUTPUT TAPE 3,  35,(I,J,VECTOR(I,J), J= IP1,NOVMI )           ESS04
  890 WRITE OUTPUT TAPE 3, 40, (I,VECTOR(I,NOVAR),I=1,NOVMI)              ESS04
 1000 NOSTEP = NOSTEP + 1                                                 ESS04
 1001 IF (VECTOR( NOVAR,NOVAR)) 1002,1002,1010                            ESS04
 1002 NSTPMI = NOSTEP - 1                                                 ESS04
      WRITE OUTPUT TAPE 3, 1004, NSTPMI                                   ESS04
      GO TO 1381                                                          ESS04
 1010 SIGY =  SIGMA(NOVAR) * SQRTF (VECTOR(NOVAR,NOVAR)/ DEFR)            ESS04
 1015 DEFR =DEFR-1.0                                                      ESS04
 1016 IF (DEFR )  1017,1017, 1020                                         ESS04
 1017 WRITE OUTPUT TAPE  3, 1019, NOSTEP                                  ESS04
      GO TO 1381                                                          ESS04
 1020 VMIN = 0.0                                                          ESS04
 1030 VMAX = 0.0                                                          ESS04
 1035 NOIN = 0                                                            ESS04
 1040 DO 1050  I = 1,NOVMI                                                ESS04
 1041 IF (VECTOR (I,I)) 1042,1050,1060                                    ESS04
 1042 WRITE OUTPUT TAPE 3, 1044, I, NOSTEP                                ESS04
 1045 GO TO 910                                                           ESS04
 1060 IF(VECTOR(I,I) - TOL)   1050,1080,1080                              ESS04
 1080 VAR = VECTOR(I,NOVAR) * VECTOR(NOVAR,I) / VECTOR(I,I)               ESS04
 1090 IF(VAR)1100,1050,1110                                               ESS04
 1100 NOIN = NOIN + 1                                                     ESS04
 1120 INDEX(NOIN) = I                                                     ESS04
 1130 COEN(NOIN)   = VECTOR(I,NOVAR) * SIGMA(NOVAR) / SIGMA (I)           ESS04
 1140 SIGMCO(NOIN) = (SIGY / SIGMA(I)) * SQRTF(VECTOR(I,I))               ESS04
      RATIO(NOIN) =  COEN(NOIN) / SIGMCO(NOIN)                            ESS04
 1150 IF (VMIN) 1160,1170,904                                             ESS04
  904 WRITE OUTPUT TAPE  3, 906                                           ESS04
      GO TO 910                                                           ESS04
 1170 VMIN = VAR                                                          ESS04
 1180 NOMIN = I                                                           ESS04
 1190 GO TO 1050                                                          ESS04
 1160 IF(VAR - VMIN)1050,1050,1170                                        ESS04
 1110 IF (VAR - VMAX)1050,1050,1210                                       ESS04
 1210 VMAX = VAR                                                          ESS04
 1220 NOMAX = I                                                           ESS04
 1050 CONTINUE                                                            ESS04
 1230 IF (NOIN) 903,1240,1245                                             ESS04
  903 WRITE  OUTPUT TAPE 3, 907                                           ESS04
      GO TO  910                                                          ESS04
 1240 WRITE OUTPUT TAPE 3,65, SIGY                                        ESS04
 1260 GO TO 1350                                                          ESS04
 1245 IF (IFCNST) 900,1250,1246                                           ESS04
 1246 CNST = 0.0                                                          ESS04
 1247 GO TO 1300                                                          ESS04
```

SUBROUTINE ESS04 (CONTINUED)

MULTIPLE LINEAR REGRESSION CALCULATIONS

```
1250 CNST = AVE(NOVAR)
1270 DO 1280 I = 1,NOIN
1290 J = INDEX(I)
1280 CNST = CNST - (COEN(I) * AVE(J))
1300 IF(IFSTEP) 900,1310,1320
1310 IF (NOENT) 1311,1311,1313
1311 WRITE OUTPUT TAPE 3, 91,NOSTEP, K
1312 GO TO 1314
1313 WRITE OUTPUT TAPE 3, 92,NOSTEP, K
1314 WRITE OUTPUT TAPE 3,70,FLEVEL, SIGY,CNST,
    1(INDEX(J),COEN(J),SIGMCO(J),RATIO(J),J=1,NOIN )
1315 GO TO NUMBER, (1320,1580)
1320 FLEVEL = VMIN * DEFR / VECTOR (NOVAR,NOVAR)
1330 IF(EFOUT + FLEVEL) 1350, 1350, 1340
1340 K =  NOMIN
1345 NOENT = 0
     GO  TO  1391
1350 FLEVEL = VMAX * DEFR / (VECTOR(NOVAR,NOVAR)-  VMAX)
1360 IF (EFIN - FLEVEL) 1370,1361,1380
1361 IF (EFIN) 1380,1380,1370
1370 K = NOMAX
1390 NOENT =  K
1391 IF(K) 1392,1392,1400
1392 WRITE OUTPUT TAPE3, 1395, NOSTEP
1394 GO TO 910
1400 DO 1410   I = 1,NOVAR
1420 IF (I-K) 1430,1410,1430
1430 DO 1440   J = 1, NOVAR
1450 IF (J-K) 1460,1440,1460
1460 VECTOR(I,J) = VECTOR(I,J) - (VECTOR(I,K) * VECTOR (K,J) / VECTOR
    -(K,K))
1440 CONTINUE
1410 CONTINUE
1470 DO 1480  I = 1, NOVAR
1490 IF (I-K) 1500,1480,1500
1500 VECTOR (I,K)  =  -  VECTOR (I,K) / VECTOR (K,K)
1480 CONTINUE
1510 DO 1520 J = 1, NOVAR
1530 IF (J-K) 1540,1520,1540
1540 VECTOR(K,J) =   VECTOR (K,J) / VECTOR (K,K)
1520 CONTINUE
1550 VECTOR(K,K) =  1.0 / VECTOR(K,K)
1560 GO TO 1000
1360 WRITE OUTPUT TAPE 3, 75,
    9          NOSTEP
1381 IF(IFSTEP)  900,1581,1570
1570 ASSIGN  1580  TO NUMBER
1571 GO TO  1310
1580 GO TO 1581
1581 IF( IFPRED)  900,1582,910
1582 REWIND 8
1583 WRITE OUTPUT TAPE 3, 85
     CUMSUM = 0.
1590 DO  1660   N = 1, NODATA
1600 READ TAPE  8,(DATA(L),L= 1, NOVAR), RUN
1610 YPRED = CNST
1620 DO 1630  I = 1,NOIN
1640 K = INDEX(I)
1630 YPRED=  YPRED +  COEN(I) * DATA(K)
1650 DEV  =  DATA(NOVAR) -  YPRED
     CUMSUM = CUMSUM + DEV
1660 WRITE OUTPUT TAPE 3,80  , RUN,DATA(NOVAR) ,YPRED, DEV, CUMSUM
 910 IF ACCUMULATOR OVERFLOW 6000,6001
6001 IF QUOTIENT OVERFLOW 6000,6002
6002 IF DIVIDE CHECK 6000,100
6000 WRITE OUTPUT TAPE 3, 6004
 100 CONTINUE
     RETURN
6004 FORMAT(79HOVIEW RESULTS WITH SKEPTICISM. OVERFLOW,UNDERFLOW OR DIV
    1IDE CHECK HAS OCCURRED.)
C    END...
   5 FORMAT (3F10.5,3I5,1H 10I2)
   6 FORMAT
    9 ( 1H  , 3F10.5 , 3I5,  1H  , 10I2  )
  10 FORMAT (6(F12.5))
  11 FORMAT ( 1H , 1PE12.5,  8E12.5    )
  15 FORMAT (1H 49H                              SUM  OF  VARIABLES//)
  20 FORMAT (1H 11H     SUM X( I2,3H) = E12.4,8H  SUM X( I2,3H) =E12.4,
    18H  SUM X( I2,3H) =E12.4,8H  SUM X(I2,3H) =E12.4 )
  25 FORMAT (17H      SUM   Y   =E12.4)
  30 FORMAT(1H0 70H                              RAW  SUM  OF SQUARES  A
    1ND  CROSS PRODUCTS// )
  35 FORMAT (1H 7H     X(I2,7H) VS X(I2,3H) = E15.6,
    1         6H    X(I2,7H) VS X(I2,3H) = E15.6,
    2         6H    X(I2,7H) VS X(I2,3H) = E15.6  )
  40 FORMAT (1H 7H     X(I2,12H) VS   Y   =E15.6,
    1         6H    X(I2,12H) VS   Y   =E15.6,
    2         6H    X(I2,12H) VS   Y   =E15.6  )
  45 FORMAT (1H 21H     Y     VS   Y    =E15.6)
  50 FORMAT (1H063H                                AVERAGE  VALUE  OF
    -  VARIABLES// )
  55 FORMAT(1H077H                          RESIDUAL  SUMS  OF  SQUA
    -RES  AND  CROSS PRODUCTS//)
  60 FORMAT(1H069H                                 PARTIAL  CORRELATI
    -ON  COEFFICIENTS//)
  65 FORMAT (25H0  STANDARD ERROR OF Y = F12.6 )
  70 FORMAT (11H   F LEVEL  F12.4/25H   STANDARD ERROR OF Y = F12.4/12H
    1   CONSTANT E13.5/56H              VARIABLE   COEFFICIENT   STD ERR
    2OR OF COEF   17H  COEF/STD ERROR  // (16H              X- I3,
    33E18.5))
  75 FORMAT (10H COMPLETED I5,20H STEPS OF REGRESSION)
  90 FORMAT(22H0STEPWISE  REGRESSION //12H PROBLEM NO I10  //13H NO OF
    1DATA = I5 //18H NO OF VARIABLES = I10 //30H WEIGHTED DEGREES OF FR
    2LLDOM = F12.2 //28H F LEVEL TO ENTER VARIABLE = F10.5 //29H F LEVE
```

SUBROUTINE ESSO4

(CONTINUED)

MULTIPLE LINEAR REGRESSION CALCULATIONS

```
    3L TO REMOVE VARIABLE = F10.5  /// )                                 ESSO4   313
    91 FORMAT (9HOSTEP NO.I5 /19H   VARIABLE REMOVED I8)                 ESSO4   314
    92 FORMAT (9HOSTEP NO.I5 /20H   VARIABLE ENTERING I8)                ESSO4   315
    93 FORMAT (5H RUN  F6.0,3H   F10.5,3H   F10.5,3H   F10.5,3H   F10.5, ESSO4   316
    13H   F10.5/(14H                F10.5,3H   F10.5,3H   F10.5,3H   F10. ESSO4   317
    25,3H   F10.5))                                                      ESSO4   318
   654 FORMAT (31H  ZERO NUMBER OF DATA. SO LONG.)                       ESSO4   319
   905 FORMAT (42H ERROR IN CONTROL CARD, PROBLEM TERMINATED)            ESSO4   320
   906 FORMAT (25H ERROR, VMIN PLUS, SOLONG)                             ESSO4   321
   907 FORMAT (26H  ERROR,NOIN MINUS, SOLONG )                           ESSO4   322
  1004 FORMAT (1H037HY SQUARE NON-POSITIVE,TERMINATE STEP  I 5)          ESSO4   323
  1019 FORMAT (1H029H NO MORE DEGREES FREEDOM STEP I 5 )                 ESSO4   324
  1044 FORMAT (1H010H SQUARE X-I5,17H NEGATIVE. SOLONG I5,6H STEPS)      ESSO4   325
  1395 FORMAT (12H  K=0. STEP I6, 7H SOLONG)                             ESSO4   326
  6112 FORMAT(38HOTOTAL CORRELATION COEFFICIENT SQUARED   F10.5 )        ESSO4   327
  4300 FORMAT(7E16.8)                                                    ESSO4   328
  5003 FORMAT( 1H1, 25X, 12A6  )                                         ESSO4   329
  4000 FORMAT(12A6)                                                      ESSO4   330
    80 FORMAT(7X , F12.5,2X,F12.5,3X,F12.5, 2X,F12.5,2X,F12.5 )          ESSO4   331
    H5 FORMAT(1H043H                PREDICTED VS ACTUAL RESULTS   /75H   ESSO4   332
    1        RUN NO.     ACTUAL        PREDICTED     DEVIATION   CUMMLATIV ESSO4   333
    2E SUM)                                                              ESSO4   334
  5000 FORMAT( 6F12.5)                                                   ESSO4   335
       END                                                               ESSO4   336
```

MONSANTO RESEARCH CORPORATION FLAME SPEED REGRESSION - ROUTINE 1922 - MODIFICATION 1 - RUN 3

MONSANTO RESEARCH CORPORATION TEST DATA FOR ROUTINE 1922

RUN 3 NUMBER OF PROBLEMS IN THIS RUN 3 HIGHEST CONTRIBUTOR CODE NUMBER IN USE 200

ACCEPTABLE DATA SOURCE NUMBER 0 ACCEPTABLE EXPERIMENTAL CONDITIONS NUMBER 0

ENTRIES TO BE READ FROM THE INPUT DATA CARDS

CARD TYPE	NUMBER OF ENTRIES	LIST SIGNIFICANCE
-L-	0	- UNACCEPTABLE DATA GROUP SERIAL NUMBERS
-M-	0	- ACCEPTABLE FUEL CLASS NUMBERS
-N-	0	- ACCEPTABLE FUEL CLASS-GROUP NUMBERS
-O-	0	- UNACCEPTABLE FUEL-CLASS-GROUP-MEMBER NUMBERS
-P-	3	- CONTRIBUTOR COUNT TEST NUMBERS
-Q-	1	- CONDITIONAL COUNT TEST CRITERIA
-R-	0	- OVERRIDING DECIMAL REGRESSION CONTROL DATA
-S-	0	- OVERRIDING INTEGER REGRESSION CONTROL DATA

LIST OF CONTRIBUTOR COUNT TESTS

1 0 37 4 40 0

LIST OF COUNT TEST CRITERIA

1

ESSO REGRESSION CONTROL LIST

0.00100 0.00002 0.00001 1 0 1 1 1 1 0 1

LIST OF ACCEPTED DATA SERIAL NUMBERS AND FUEL NAMES

2 ETHANE	3 PROPANE	4 NBUTANE	5 NPENTANE	6 N-HEXANE	7 NHEPTANE
8 NOCTANE	9 N-DECANE	10 N-UNDECANE	11 N-TRIDECANE	12 ISOBUTANE	13 ISO-PENTANE
14 22MEPROPANE	15 2-ME-PENTANE	16 3-ME-PENTANE	17 23MEBUTANE	18 22MEBUTANE	19 24MEPENTANE
20 234MEPENTANE	21 224MEPENTANE	22 225MEHEXANE	23 CYCLOPROPANE	24 CYCLOPENTNE	25 CYCLOHEXANE
26 MECYCPENTANE	27 MECYCHEXANE	28 12MECYCHEX-C	29 12MECYCHEX-T	31 PROPYLENE	32 BUTENE-1
33 CIS-BUTENE-2	34 TR-BUTENE 2	35 N-PENTENE-1	36 NPENTENE-2	37 ISO-BUTYLENE	38 3ME-BUTENE-1
39 2-MEBUTENE-1	40 2-MEBUTENE-2	41 4MEPENTEN-2C	42 4MEPENTEN-2T	43 244MEPENTNE1	45 2MEBUTDENE13
46 CYCLOHEXENE	47 4VINCYCHEX-1	48 CYCOCTDENE15	49 PROPYNE	50 1-BUTYNE	52 TOLUENE
53 PARAXYLENE	54 ETHYLBENZENE	55 SECBUBENZENE	56 TERTBUBENZNE	57 1-F-PENTANE	58 1-F-HEXANE
59 1-1DIFLETHAN	60 1-4FBUTANE	61 111FPENTANE	63 ME-CHLORIDE	64 ET-CHLORIDE	65 NPRCHLORIDE
66 NBUCHLORIDE	67 2BUCHLORIDE	68 1-CLPENTANE	69 1CL2MEPRPANE	70 2CL2MEPRPANE	71 1-4CLBUTANE
72 1-2CLBUTANE	74 2-CL-PROPENE	75 ALLYLCHLRIDE	76 2CLBUTENE-2	77 ETHANOL	78 N-PROPANOL
79 ETHYLACETATE	80 3MEBORATE	81 ME-N-AML-KET	82 DI-ME-ETHER	83 VI-ME-ETHER	84 P-F-ANISOLE
85 ME-PH-KETONE	86 ME4FPHKETONE	87 MEBENZOATE	88 M-CRESOL	89 1-3CLPROPANE	90 1-2CLPROPANE
91 1-BRBUTANE	92 1-2CL-ETHANE	93 1-BR-PENTANE	94 2BR-BUTENE-2	95 3-BR-PROPENE	96 CL-22FPRPANE
97 1-2CL2FPRPAN	99 M-F-TOLUENE	111 N-BU-AMINE	112 4ME-PYRIDINE	113 ETHLNDIAMINE	114 2ME-PYRIDINE
116 11MEPRBENZNE	117 ISOPRCHLRIDE	119 ISPRPYLBNZNE	120 N-BUTBENZENE	121 124MEBENZENE	122 SECBUBENZENE
124 ORTHOXYLENE	125 METAXYLENE	126 ANISOLE	127 1-F-PENTANE	128 26-LUTIDINE	129 NPRCHLORIDE
130 N-HEXANE	133 1-CLPENTANE	134 2BUTANETHIOL	135 1-F-HEXANE	136 ETHYL3AMINE	137 DIISOPRSLFNE
138 DIISOPRSLFOX	139 N-BU-SULFIDE	140 ISOBUMRCAPTN	142 PROPANE		

MONSANTO RESEARCH CORPORATION FLAME SPEED REGRESSION - ROUTINE 1922 - MODIFICATION 1 - RUN 3

PROBLEM 1

DEPENDENT VARIABLE = 3 UMAX/5 CMAX X10^{-18}

LIST OF INDEPENDENT CONTRIBUTORS WITH THEIR CORRESPONDING REGRESSION INDICIES

0	1	2	3	4	5	6	7	8	9
	37 PRIM-H	38 SEC-H	39 TERT-H						

```
                    1 TITLE CARD FOR ESSO REGRESSION PROGRAM
STEPWISE  REGRESSION

PROBLEM NO          1

NO OF DATA =  118

NO OF VARIABLES =           4

WEIGHTED DEGREES OF FREEDOM =       118.00

F LEVEL TO ENTER VARIABLE =   0.00002

F LEVEL TO REMOVE VARIABLE =   0.00001


   STANDARD ERROR OF Y =   170.257925

 STEP NO.     1
   VARIABLE ENTERING        1
   F LEVEL      315.6645
   STANDARD ERROR OF Y =         88.6189
   CONSTANT    0.
               VARIABLE    COEFFICIENT    STD ERROR OF COEF    COEF/STD ERROR

                 X-  1      0.23460E 02       0.13200E 01        0.17773E 02

 STEP NO.     2
   VARIABLE ENTERING        2
   F LEVEL      110.1560
   STANDARD ERROR OF Y =         63.6083
   CONSTANT    0.
               VARIABLE    COEFFICIENT    STD ERROR OF COEF    COEF/STD ERROR

                 X-  1      0.18738E 02       0.10489E 01        0.17864E 02
                 X-  2      0.12318E 02       0.11736E 01        0.10496E 02

 STEP NO.     3
   VARIABLE ENTERING        3
   F LEVEL        0.5730
   STANDARD ERROR OF Y =         63.7267
   CONSTANT    0.
               VARIABLE    COEFFICIENT    STD ERROR OF COEF    COEF/STD ERROR

                 X-  1      0.19356E 02       0.13313E 01        0.14540E 02
                 X-  2      0.12241E 02       0.11802E 01        0.10372E 02
                 X-  3     -0.84304E 01       0.11137E 02       -0.75695E 00
 COMPLETED    3 STEPS OF REGRESSION
```

APPENDIX C

Fortran Programs for Routines
FSRTL and FSRDM

ROUTINE FSRTL

MASTER LIBRARY TAPE PREPARATION FROM CARD LIBRARY

```
CFSRTL    MASTER TAPE PREPARATION FOR FLAME SPEED REGRESSION ROUTINE
      DIMENSION  D(6), LFGCCN(200), FGCL(200), GNL(200),DNM(6)
C       INPUT DATA FROM CARD IMAGES ON TAPE 2
C       MASTER TAPE LOGICAL UNIT 6
      REWIND 6
C       TITLE CARD
      READ INPUT TAPE 2, 1000
      WRITE OUTPUT TAPE 6, 1000
C       NUMBER OF GROUPS ON TAPE
      READ INPUT TAPE 2, 1001, IPI
      WRITE OUTPUT TAPE 6,1001, IPI
C       MAIN DATA GROUPS
      DO 20 I=1, IPI
      READ INPUT TAPE 2,1002, ISFN, FN1, FN2, IFNC, IFNG, IFNM,
     1      INDS, INEC, ( D(K), K=2,6), IPFGC,(LFGCCN(K), FGCL(K),K=1,
     2      IPFGC )
   20 WRITE OUTPUT TAPE 6,2002,ISFN,FN1, FN2, IFNC, IFNG, IFNM,
     1      INDS, INEC, ( D(K), K=2,6), IPFGC,(LFGCCN(K), FGCL(K),K=1,
     2      IPFGC )
C       CONTRIBUTOR NAMES
      READ INPUT TAPE 2, 1003,(GNL(I),I=1, 200)
      WRITE OUTPUT TAPE 6,2003,(GNL(I),I=1, 200)
C       DEPENDENT VARIABLES
      READ INPUT TAPE 2, 1003, (DNM(I), I=1,6)
      WRITE OUTPUT TAPE 6, 2003, (DNM(I),I=1, 6)
      END FILE 6
      REWIND 6
      WRITE OUTPUT TAPE 3, 2005
      CALL EXIT
 1000 FORMAT(1H1,11X, 60H
     1                    )
 1001 FORMAT(1H0, I6)
 1002 FORMAT(I6, 2A6, 5I6, 2F12.5  / 3F12.5, I6, I6, F12.5 /(I6, F12.6,
     1         I6, F12.6, I6, F12.6, I6, F12.6 ) )
 1003 FORMAT(12A6)
 2002 FORMAT(1H0, I6, 2A6, 5I6, 1P5E12.4, I6/ (1H , I6, E12.4, I6, E12.4
     1      , I6, E12.4, I6, E12.4, I6, E12.4, I6, E12.4 ))
 2003 FORMAT(1H0, 9(6X,A6)/(1H , 6XA6, 6XA6, 6XA6, 6XA6, 6XA6, 6XA6,
     1       6XA6, 6XA6, 6XA6 ) )
 2005 FORMAT(1H1, 25X,28HTAPE 6 PREPARATION COMPLETE  )
      END
```

ROUTINE FSRDM

MASTER CARD LIBRARY MODIFICATION

```
CFSRDM   MASTER DECK MODIFICATION FOR FLAME SPEED REGRESSION ROUTINE      FSRDM
C      PREPARE TAPE 14 FOR PUNCHING OF CHANGES IN MASTER TAPE             FSRDM
C      NOMENCLATURE                                                       FSRDM
C      NDGPOT           - NUMBER OF DATA GROUPS PREVIOUSLY ON TAPE        FSRDM
C      NDGCOT           - NUMBER OF DATA GROUPS CURRENTLY ON TAPE         FSRDM
C      NDGCHG           - NUMBER OF DATA GROUPS ALTERED                   FSRDM
C      IDGCHG(K)        - CODE NUMBER OF ALTERED DATA GROUPS              FSRDM
C      NADD             - NUMBER OF DATA GROUPS ADDED TO MASTER DECK      FSRDM
C      ICONAM           - CONTRIBUTOR NAME PUNCH SWITCH  1-PUNCH  2-OMIT  FSRDM
C      IDPNAM           - DEPENDENT VARIABLE PUNCH SWITCH 1-PUNCH 2-OMIT  FSRDM
      DIMENSION IDGCHG(10000) ,LFGCCN(90), FGCL(90), GNL(200), DNM(6)     FSRDM
     1., D(6)                                                             FSRDM
      REWIND 6                                                            FSRDM
C      READ INPUT CONTROL DATA                                            FSRDM
      READ INPUT TAPE 2, 3000, NOGPOT, NDGCHG, ICONAM, IDPNAM             FSRDM
      IF( NDGCHG) 10, 20, 10                                              FSRDM
   10 READ INPUT TAPE 2, 3001, (IDGCHG(K), K=1, NDGCHG )                  FSRDM
C      READ TITLE AND NUMBER OF GROUPS FROM MASTER TAPE AND PUNCH         FSRDM
   20 READ INPUT TAPE 6, 1000                                             FSRDM
      READ INPUT TAPE 6, 1001, NDGCOT                                     FSRDM
      WRITE OUTPUT TAPE 14, 1000                                          FSRDM
      WRITE OUTPUT TAPE  3, 1000                                          FSRDM
      L = 1                                                               FSRDM
      WRITE OUTPUT TAPE 14, 1001, NDGCOT                                  FSRDM
      WRITE OUTPUT TAPE  3, 1001, NDGCOT                                  FSRDM
      IF( NDGCOT - NDGPOT) 100, 30, 30                                    FSRDM
   30 DO 45  I=1, NDGCOT                                                  FSRDM
      READ INPUT TAPE 6  ,2002,ISFN,FN1, FN2, IFNC, IFNG, IFNM,           FSRDM
     1      INDS, INEC, ( D(K), K=2,6), IPFGC,(LFGCCN(K), FGCL(K),K=1,    FSRDM
     2      IPFGC )                                                       FSRDM
      IF( I - NDGPOT) 32, 32, 36                                          FSRDM
   32 IF( I - IDGCHG(L) ) 40, 33, 40                                      FSRDM
   33 L = L + 1                                                           FSRDM
   36 WRITE OUTPUT TAPE14,1002,ISFN,FN1, FN2, IFNC, IFNG, IFNM,           FSRDM
     1      INDS, INEC, ( D(K), K=2,6), IPFGC,(LFGCCN(K), FGCL(K),K=1,    FSRDM
     2      IPFGC )                                                       FSRDM
   40 WRITE OUTPUT TAPE 3,2002,ISFN,FN1, FN2, IFNC, IFNG, IFNM,           FSRDM
     1      INDS, INEC, ( D(K), K=2,6), IPFGC,(LFGCCN(K), FGCL(K),K=1,    FSRDM
     2      IPFGC )                                                       FSRDM
   45 CONTINUE                                                            FSRDM
      READ INPUT TAPE 6   , 2003, (GNL(I), I=1, 200)                      FSRDM
      READ INPUT TAPE 6   , 2003, (DNM(I), I=1, 6 )                       FSRDM
      GO TO (50, 60),ICONAM                                               FSRDM
   50 WRITE OUTPUT TAPE 14, 1003, (GNL(I), I=1, 200)                      FSRDM
      WRITE OUTPUT TAPE  3, 1003, (GNL(I), I=1, 200)                      FSRDM
   60 GO TO (70, 80), IDPNAM                                              FSRDM
   70 WRITE OUTPUT TAPE 14, 1003, (DNM(I), I=1, 6 )                       FSRDM
      WRITE OUTPUT TAPE  3, 1003, (DNM(I), I=1, 6 )                       FSRDM
   80 WRITE OUTPUT TAPE 3, 4000                                           FSRDM
   90 CALL EXIT                                                           FSRDM
  100 WRITE OUTPUT TAPE 3, 4001                                           FSRDM
      GO TO 90                                                            FSRDM
 1000 FORMAT(1H1,11X, 60H                                                 FSRDM
     1                      )                                             FSRDM
 1001 FORMAT(1H0, I6)                                                     FSRDM
 1002 FORMAT(I6, 2A6, 5I6, 2E12.5  / 3E12.5, I6, I6, E12.5 /(I6, E12.5,   FSRDM
     1      I6, E12.5, I6, E12.5, I6, E12.5))                             FSRDM
 1003 FORMAT(12A6)                                                        FSRDM
 2002 FORMAT(1H0, I6, 2A6, 5I6, 1P5E12.4, I6/ (1H , I6, E12.4, I6, E12.4  FSRDM
     1      , I6, E12.4, I6, E12.4, I6, E12.4, I6, E12.4 ))               FSRDM
 2003 FORMAT(1H0, 9(6X,A6)/(1H , 6XA6, 6XA6, 6XA6, 6XA6, 6XA6, 6XA6,      FSRDM
     1          6XA6, 6XA6, 6XA6 ) )                                      FSRDM
 3000 FORMAT( 4I6)                                                        FSRDM
 3001 FORMAT(  12I6)                                                      FSRDM
 4000 FORMAT(1H1, 25X, 35HMASTER DECK MODIFICATION COMPLETE    )          FSRDM
 4001 FORMAT(1H1, 25X,40HERROR - MORE DATA GROUPS IN LIBRARY THAN ON TAP  FSRDM
     1E   )                                                               FSRDM
      END                                                                 FSRDM
```

Aeronautical Systems Division, Dir/Aeromechanics Flight Accessories Lab, Wright-Patterson AFB, Ohio
Rpt No. ASD-TDR-63-182. FLAME SPEED DATA REDUCTION AND CORRELATION USING A DIGITAL COMPUTER. Final report, Feb 63, 89 p. incl illus., tables, 6 refs.

Unclassified Report

Two digital computer routines were developed to process flame speed data resulting from the burning of compounds in air oxygen, and to correlate particular structural configuration with flame speed.

In both routines, a high degree of flexibility has been incorporated to assure efficient utilization under several forseeable circumstances.

The first routine, FSC, processes the raw experimental data to obtain flame speeds, equivalence ratios, and the equivalence ratio at the maximum flame speed. This information is stored on a master magnetic tape for subsequent calculations.

The second routine, FSR, permits selection of specific data groups from the master tape for analysis. A linear model was chosen for the correlation.

1. Computer & Data Systems
2. Flame Speed Data
3. Correlation Technique

I. AFSC Project 6075, Task 607505
II. Contract AF33(657)-7617
III. Monsanto Research Corp., Dayton, Ohio
IV. G. H. Ringrose, et al.
V. Aval fr OTS
VI. In ASTIA collection

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IV. G. H. Ringrose, et al.
V. Aval fr OTS
VI. In ASTIA collection